STATE OF OHIO
FRANK J. LAUSCHE, Governor
DEPARTMENT OF NATURAL RESOURCES
A. W. MARION, Director
DIVISION OF GEOLOGICAL SURVEY
JOHN H. MELVIN, Chief

FOURTH SERIES, BULLETIN 49

LIMESTONES OF EASTERN OHIO

BY

RAYMOND E. LAMBORN

COLUMBUS
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COMMISSION MEMBERS

Warner P. Simpson Co.
Columbus, Ohio
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INTRODUCTION

Location and Area

The most extensive deposits of limestone and dolomite reaching the surface in Ohio are found in the western half of the State. The general features of these carbonate rocks with special attention to chemical composition has been well considered by Wilber Stout in Bulletin 42 of the Geological Survey of Ohio entitled Limestones and Dolomites of Western Ohio, published in 1941. The present report deals with the eastern half of Ohio comprising 41 counties having a total combined area of 20,055 square miles. Its western edge includes those counties lying wholly east of a line extending from the Ohio River at Vanceburg to Lake Erie at Port Clinton excepting Huron and Erie in the northern part. The counties considered here in alphabetic order are as follows: Ashland, Ashtabula, Athens, Belmont, Carroll, Columbiana, Coshocton, Cuyahoga, Fairfield, Gallia, Geauga, Guernsey, Harrison, Hocking, Holmes, Jackson, Jefferson, Knox, Lake, Lawrence, Licking, Lorain, Mahoning, Medina, Meigs, Monroe, Morgan, Morrow, Muskingum, Noble, Perry, Portage, Richland, Scioto, Stark, Summit, Tuscarawas, Trumbull, Vinton, Washington, and Wayne. In the region thus defined the sedimentary series reaching the surface consists of beds of Upper Devonian, Mississippian, Pennsylvanian, and Permian ages, having a total vertical thickness in excess of 3,000 feet.

Purpose of Report

Some data on the chemical composition of the limestones in the eastern part of the State have appeared from time to time in various publications of the Geological Survey of Ohio. Chief among such publications is Bulletin 4 by Edward Orton, Jr., and S. V. Peppel entitled The Limestone Resources and the Lime Industry in Ohio, published in 1906. Other publications include county reports by Wilber Stout on Geology of Southern Ohio (Bulletin 20, 1916), Geology of Muskingum County (Bulletin 21, 1918), Geology of Vinton County (Bulletin 31, 1927) and by Wilber Stout and R. E. Lamborn on the Geology of Columbiana County (Bulletin 28, 1924). In some of these publications too little attention has been given to the description of the limestone deposits and too few determinations reported in the chemical analyses to meet present-day requirements. To supplement published data with detailed analyses in areas already surveyed and to record general geology, detailed descriptions, and chemical composition of limestone deposits occurring in areas hitherto not sampled, is the chief purpose of this report. No special attention has been given to quarrying methods, plant preparation, requirements of limestone for various uses, or market conditions. Owing to the time involved and to the expense of chemical work it has not been possible to sample all quarries. In field work it has seemed advisable to so spread the samples that those deposits be included which are deemed of unusual importance on the one hand or are considered typical of a stratigraphic horizon on the other. It is believed that this report will be of value to those interested in limestone resources of eastern Ohio in that it gives county by county a brief picture of the stratigraphic sequence, the character, thickness, and distribution of the limestone formations involved, and a detailed study of the composition.

Field Work and Acknowledgments

The field work necessary to the preparation of Bulletin 42 on the Limestones and Dolomites of Western Ohio by Wilber Stout was completed in 1940. The following year the State Geologist deemed it advisable to extend the chemical investigations to include the limestones of eastern Ohio, the results to be included in a separate publication. Accordingly work on the project was begun by R. E. Lamborn during the field season of 1941 and continued at intervals during the summers of 1942, 1943, 1944, and 1946. The first 55 samples collected during this investigation were analyzed by the late Mr. Downs Schaaf at his laboratory at 1433 Studer Ave., Columbus, Ohio. Chemical work ceased early in 1942 and was not again resumed until 1946. Additional samples were analyzed during 1946, 1948, and 1949 in the Nalin Laboratories, 2641 Cleveland Ave., Columbus, Ohio, and by E. Chadbourn, analyst, Rock Analysis Laboratory, University of Minnesota, Minneapolis, Minnesota. Some analyses of a somewhat earlier date by D. J. Demorest of the Ohio State University have also been included in the report.

In the sampling of the limestones detailed measurements and descriptions were made of the exposures. Fresh exposures were selected wherever possible. On natural exposures or outcrops the surface coating was removed before sampling in order to reduce the effects of surface weathering. Calcareous shale partings between limestone layers were discarded. In sampling the limestones pieces were broken in vertical section from each layer in quantity proportional to its thickness. The field samples secured in this manner, weighing from 10 to 100 pounds or so per sample, were submitted to the laboratory. Field samples of limestone collected in this manner are believed to yield an analysis which is average for the beds sampled.

During the course of the field work and in the preparation of the report the writer has had access to much unpublished material in the Survey office in the form of maps and field notes. Coal outcrop maps by D. D. Condit, Wilber Stout, C. R. Schroyer, George White, and R. E. Lamborn have been of aid in field in the quick identification of limestone members in the detailed and highly complex succession of the Pennsylvanian system. Unpublished field sections by Wilber Stout, George White, and others have been helpful not only in determining the distribution of limestone deposits and thus reducing the necessary field work, but also in the construction of generalized sections of specific areas. In the preparation of the report free use has been made of various publications of the Geological Survey of Ohio. Many other sources of information have also been consulted. References to sources of specific information are given in the text.

To all who have aided the project by giving information in the field, by typing the manuscript, and by reading proof during the process of publication, the writer wishes to express his thanks and appreciation.

OCCURRENCE AND CHARACTERISTICS OF LIMESTONE

Definition and General Character of Limestone

Limestone is a very common type of sedimentary rock which consists in large part of calcium carbonate but generally contains varying amounts of magnesium carbonate. When the magnesium carbonate is present in an amount equal molecularly to the calcium carbonate, the rock is generally termed a dolomite. Rocks having compositions intermediate between the pure limestone free of magnesium carbonate on the one hand and dolomite on the other are often recognized but not clearly defined by name. With increasing amount of magnesium carbonate intermediate types are often termed magnesium limestone, dolomitic limestone, and limy dolomite. In addition to the carbonates of calcium and magnesium, limestones generally contain impurities in small but varying amounts. Chief among these are silica in the form of quartz or flint and chert, hydrated aluminum silicates, hydrated ferric oxide, ferrous carbonate, and iron disulphide. Others generally present in minute quantities include calcium phosphate, sulphates of calcium, and possibly strontium and barium, manganese carbonate, and organic matter.

Like other types of sedimentary rocks with which it is associated, limestone occurs in layers or strata separated by calcareous shale partings or by bedding planes only. The beds or strata may be thick or thin, may be regular in character, or nodular and broken in appearance. They may extend for miles with little variation in thickness or apparent change in lithologic character, or they may be lens-like with short horizontal duration. In their field relationships limestone formations may grade laterally or vertically into calcareous shale by an increase in the amount of silt and clay impurities or into calcareous sandstone by the introduction of sand. In any sedimentary series approximations as to the identity and purity of limestones are indicated by the physical character of the stone and by its reaction with acid. Cold dilute hydrochloric acid produces rapid effervescence of carbon dioxide on application to limestone and a much slower reaction with dolomite.

The physical character of limestone varies greatly depending in large part upon the texture of the stone and upon the character, quantity, and distribution of the impurities present. In texture the limestone may be compact with individual particles closely united, or it may be porous or full of minute cavities as in oolitic and shell limestones. The stone may be dense and homogeneous where the crystals are too small to be observed by the naked eye or it may be partially or wholly crystalline as indicated by the glistening surfaces of cleavage planes. The natural color of pure limestone is white or gray. However, the presence of various impurities in a finely divided conditions and often in minute quantities generally makes a great change in the appearance of the rock. Finely divided organic material produces a gray, greenish black, gray-black, or black color, the shade deepening with the increase in amount present. Iron disseminated in a carbonate form may be colorless or yield a faint brownish tint. On oxidation shades of cream, buff, yellow, brown, pink, or red may result. Common impurities such as quartz, clay matter, and traces of gypsum, calcium phosphate, and manganese carbonate, have slight effect on the color of the stone.

Other physical properties, such as hardness or resistance to abrasion and toughness or resistance to fracture, vary greatly in limestone. Here textural variations and changes in the character of the impurities present may both play a part. Where sand, flint, or iron carbonate are conspicuous, the stone is generally hard and tough. Argillaceous or clay-bearing limestones are generally soft and friable. Other characteristics similar, compact limestones are generally tougher than porous ones. Dense compact specimens may be tougher than coarsely crystalline samples. Such characteristics may influence ease of quarrying and adaptability of stone to various construction purposes.

Origin of Limestone

Limestones have been formed by the consolidation of calcareous sediments. Such sediments in the form of ooze and shell fragments originated in shallow waters chiefly through the agency of living organisms either plant, animal, or both, and to a less extent by direct chemical precipitation of calcium carbonate from solution. The primary or original source of the calcium carbonate is from the decomposition of igneous rocks by carbonated waters. The calcium bicarbonate ($Ca(HCO_3)_2$) is transported in solution by streams to inland bodies of water or to the sea. Here many small aquatic animals remove the calcium carbonate from solution and utilize it for shells or other hard skeletal parts. On death the shells may be preserved, may be broken by wave action to form calcareous sands, or may be further reduced to calcareous muds. Some aquatic plants withdraw carbon dioxide from bicarbonate solutions and are thus instrumental in the precipitation of calcium carbonate. In inland lakes direct chemical precipitation of calcium carbonate can be brought about by evaporation.

The rate of accumulation of calcareous sediments by the processes described above is extremely slow. Perhaps one thousand years on an average have been necessary for the deposition of calcareous sediment necessary for the production of one foot of limestone. During this period varying amounts of impurities in the form of atmospheric dust, organic matter, or water-carried sands, silts, or clays may have been added to the deposit to affect its purity. A relatively high concentration of such impurities along a sedimentation surface or zone causes structural weakness and on consolidation leads to a bedding plane. Each bed or stratum is thus conceived to represent a period of uniform deposition, whereas bedding planes or thin shale partings represent abrupt changes in physical conditions and thus the character of the sediments.

To transform the loose calcareous sediments to limestone, consolidation is necessary. Of much importance in this process is the weight of overlying beds which tends to compress and weld the materials together. The welding effect is generally accompanied by a partial or complete recrystallization of the calcium carbonate to form a network of interlocking crystals. The recrystallization is generally promoted by increased pressure, increased temperature, and the circulation of ground water. In limestones formed by the normal processes of sedimentation and consolidation the stone is rarely as holocrystalline and compact as in their metamorphosed equivalents, the marbles.

Chemical Composition of Limestone

Owing to the nature and quantity of the various impurities which were deposited with the calcium carbonate sediments and to possible chemical changes which may have taken place following its deposition, the chemical composition of limestone varies within wide limits. Some analyses expressed in oxide form showing such variation are given below.

	1	2	3	4	5
Silica, SiO_2	0.03	44.72	0.05	23.26	5.75
Alumina, Al_2O_3	0.02	1.07	0.02	5.92	1.01
Ferric oxide, Fe_2O_3	0.10	0.02	0.02	0.38	0.05
Ferrous oxide, FeO	---	0.53	0.09	2.57	3.40
Iron disulphide, FeS_2	<0.01	0.08	<0.01	<0.01	0.14
Magnesium oxide, MgO	0.28	0.33	21.77	10.22	7.63
Calcium oxide, CaO	54.66	28.72	30.32	22.92	39.42
Strontium oxide, SrO	<0.01	<0.01	<0.01	<0.01	<0.01
Barium oxide, BaO	<0.01	<0.01	<0.01	0.13	<0.01
Sodium oxide, Na_2O	<0.01	0.02	<0.01	0.04	0.02
Potassium oxide, K_2O	<0.01	0.09	<0.01	0.16	0.06
Water, hydroscopic, H_2O-	0.60	0.45	0.10	0.38	0.07
Water, combined, H_2O+	<0.01	0.30	0.01	4.19	0.30
Carbon dioxide, CO_2	42.45	23.24	47.60	28.88	41.15
Titanium dioxide, TiO_2	<0.01	0.07	<0.01	0.02	0.12
Phosphorus pentoxide, P_2O_5	<0.01	0.09	0.02	0.02	0.14
Sulphur trioxide, SO_3	1.56	0.04	<0.01	0.65	0.48
Manganous oxide, MnO	0.03	0.19	0.03	0.17	0.38
Carbon, organic, C	0.20	0.04	0.04	0.11	0.02

Hydrogen, organic, H	0.02	---	---	0.01	---
Total	99.95	100.00	100.07	100.03	100.14

1. Marl near Castalia, Erie County, Ohio, Downs Schaaf, analyst. Stout, Wilber, Marl, tufa rock, travertine, and bog ore in Ohio: Geol. Survey Ohio, Bull. 41, pp. 19-20, 1940.
2. Cambridge limestone J. A. Dixon property, Highland Township, Muskingum County, Downs Schaaf, analyst.
3. Niagara Dolomite, quarry of Dolomite, Incorporated, near Bettsville, Seneca County, Downs Schaaf, analyst.
   Stout, Wilber, Dolomites and limestones of western Ohio: Geol. Survey Ohio, Bull. 42, pp. 350-351, 1941.
4. Fishpot limestone, Lawrence King quarry, Olive Township, Noble County, analysis by Nalin Laboratories.
5. Pittsburgh limestone, Flushing Township, Belmont County, Downs Schaaf, analyst.

Mineral Constituents and Impurities in Limestone

As indicated in preceding paragraphs, limestone consists in large part of calcium carbonate, $CaCO_3$ ($CaO.CO_2$), but generally contains impurities in small but varying amounts. The most common impurities consist of compounds containing iron (Fe), aluminum (Al), silicon (Si), phosphorus (P), sodium (Na), potassium (K), manganese (Mn), sulphur (S), and titanium (Ti) with occasional traces of barium (Ba), and strontium (Sr), and generally with some chemically combined water (H_2O+). In present-day chemical analyses the composition is expressed in terms of oxides of the various elements and not as per cent composition of the various mineral constituents in the sample. In order to determine the mineral composition it is necessary to resort to qualitative and quantitative microscopic determinations on the one hand, or to compute the probable mineral composition from the chemical analysis expressed as oxides on the other. Both methods leave much to be desired in the way of accuracy. In this report the writer has computed the per cent of each of the probable mineral constituents in the samples from the chemical analysis expressed in oxide form. The results are believed to be close approximations as to identity of the various mineral constituents and per cent of each.

The chief mineral constituents in limestone and common mineral impurities reported in chemical analyses are briefly considered.

Calcium Carbonate

Calcium carbonate ($CaCO$ or $CaO.CO_2$) or calcite, is the essential mineral constituent of all limestones. When free from impurities it is white or colorless. It may crystallize in a number of different forms. In the crystalline limestones it usually occurs as irregular shaped grains which cleave in two directions which intersect at angles of 105° and 75°. The luster of the crystals is glossy or vitreous, its hardness is 3, and its specific gravity is 2.71, yielding a weight of about 169 pounds per cubic foot. Owing to porosity and the presence of impurities, Ohio limestones may vary in weight per cubic foot from 150 to 170 pounds or more. A simple distinguishing test for calcium carbonate is the rapid effervescence of carbon dioxide gas on application of cold dilute hydrochloric acid.

Magnesium Carbonate

Magnesium carbonate ($MgCO_3$ or $MgO.CO_2$) occurs in varying amounts in practically all limestone. Where present it forms with the calcium carbonate

($CaCO_3$) the double carbonate of calcium and magnesium dolomite ($CaCO_3 . MgCO_3$). When the molecular ratio of calcium carbonate to magnesium carbonate in a mineral or rock is 1:1 it is termed a dolomite. Intermediate types such as magnesium limestone, dolomitic limestone, and limy dolomite are mixtures of the calcite molecule ($CaCO_3$) and the dolomite molecule ($CaCO_3 . MgCO_3$) in varying proportions.

The origin of large proportions of magnesium carbonate in limestones is not clearly understood. It may have originated in several ways. Calcium and magnesium carbonates may have been precipitated from solution simultaneously under certain conditions. The shells from which organic limestone was derived contain small quantities of magnesium carbonate. Enrichment in magnesium carbonate may have been brought about by solution of the more soluble calcium carbonate, by replacement of some of the calcium carbonate by magnesium carbonate in solution in water before solidification of the sediments, or by similar process of replacement by magnesium in solution in circulating ground waters after the formation of the limestone.[1]

Dolomite when visibly crystalline is similar in physical properties to crystalline limestone or calcite. Its color may be white, gray, through various shades of pink to brown. Its hardness is 3.5 - 4, a little harder than calcite, and its specific gravity is 2.85, a little greater than calcite. Like calcite it has rhombohedral cleavage, but the cleavage planes in dolomite are often visibly curved. A slow effervescence of carbon dioxide results when cold dilute hydrochloric acid is applied to dolomite.

Silica

Silica (SiO_2) is present in small quantities as an impurity in practically all limestones. It may be present as quartz crystals lining the walls of minute cavities or as grains of quartz sand embedded in the stone. As the sand increases the rock becomes a sandy limestone and with further increases grades to a calcareous sandstone. In an amorphous state silica is present in many limestones as nodules or irregular beds of flint or chert or, in a less segregated form, as the siliceous skeletons of former organic organisms. Formations of this type are often called flinty, cherty, or siliceous limestones.

Silica in chemical combination with other impurities is present in clay which is found in nearly all limestones either in a finely disseminated state or concentrated in zones or along bedding planes.

Alumina

Alumina (Al_2O_3) does not occur as an oxide in limestone. It is present in chemical combination with silica, water, and possibly other basic oxide impurities such as sodium oxide (Na_2O) and potassium oxide (K_2O) to form hydrated aluminum silicates, the chief constituents in clay. Kaolin ($H_4Al_2Si_2O_9$ or $Al_2O_3 . 2SiO_2 . 2H_2O$) and sericite ($H_2(Na, K)Al_3(SiO_4)_3$ or $(Na, K)_2O . 3Al_2O_3 . 6SiO_2 . 2H_2O$) are two such common hydrated aluminum silicates. The clay material may occur in varying proportions in limestone. With increasing per cent the rock passes from a relatively pure limestone to an argillaceous limestone and, with further increase, to a calcareous shale.

Compounds of Iron

Iron in chemical combination with other elements is a common impurity in

[1] *Clarke, F. W., The data of geochemistry: U.S. Geol. Survey Bull. 770, p 578, 1924*

limestone. Here it may be present as a carbonate, a sulphide, or an oxide. Of these the ferrous carbonate, siderite, ($FeCO_3$ or $FeO.CO_2$) has the most widespread occurrence. It is generally a gray to light brown mineral which may be finely and uniformly disseminated throughout the limestone or concentrated along certain zones. Under some conditions of formation the iron oxide, hematite, (Fe_2O_3) has been deposited with the limestone giving its characteristic pink or reddish color to the rock. On weathering both the siderite and hematite are changed to limonite ($2Fe_2O_3.3H_2O$) as indicated by the yellow brown color of the weathered stone.

The brass-colored sulphide of iron, pyrite (FeS_2), is a common mineral impurity. It may occur as widely scattered crystals of microscopic size or large enough to be visible by the naked eye. Concentrations of pyrite crystals are common, however, along bedding planes and along zones bordering limestone-shale contacts. The white iron pyrite, marcasite (FeS_2), is not common in limestones.

Sulphur

Sulphur as an impurity in limestone is found chiefly in combination with iron in pyrite (FeS_2) as previously described. Sulphides of lead (PbS) and zinc (ZnS) are not unknown in limestone but they are comparatively rare. Sulphur is generally present in minute quantities in the sulphate form as in gypsum ($CaSO_4.2H_2O$) or anhydrite ($CaSO_4$). Sulphates of barium ($BaSO_4$) and strontium ($SrSO_4$) are rare in limestones.

Phosphorus

Phosphorus in small quantities is present in most limestones and it is a prominent impurity in many fossiliferous limestones. It is believed to occur as tricalcium phosphate ($Ca_3(PO_4)_2$ or $3\,CaO.P_2O_5$) which may approach the mineral apatite ($Ca_4(CaF)(PO_4)_3$) in composition.

Organic Matter

The organic material that occurs as impurities in limestone is the residue of the plant and soft animal remains incorporated in the sediments at time of their deposition. The carbonaceous matter occurring uniformly distributed or in zones generally gives the stone a dark gray to black color. When it becomes conspicuous the rock may be appropriately called a carbonaceous or bituminous limestone. Fluid and semi-solid hydrocarbons are confined to cavities or pore space. Their presence in small quantities is often indicated by the petroleum odor emitted from freshly broken surfaces. When the semi-solid hydrocarbons are a conspicuous element, the rock is often termed an asphaltic limestone. In chemical analyses a measure of organic material present is indicated by the quantity of organic carbon and hydrogen present.

Other Impurities

Other impurities which are generally present in small amounts include compounds of titanium and manganese. The titanium is probably present as a dioxide (TiO_2) whereas the manganese is believed to occur as the carbonate ($MnCO_3$ or $MnO.CO_2$).

In analyses of impure limestones of the argillaceous type, perceptible quantities of soda (Na_2O) and potash (K_2O) are generally reported. These bases are believed to be in combination with alumina and silica as hydrated aluminum silicates.

Value and Uses of Limestone

Limestone and its close kindred, dolomite, are more widely and diversely utilized than any other common variety of sedimentary rock. The use to which limestone was first applied in Ohio was for constructional purposes. In pioneer times the stone was quarried from near-by hillside or ravine, and was utilized chiefly for such simple structures as dams, building foundations, buildings, chimneys, and fireplaces. Some of the stone was calcinced to quicklime to be used for the production of mortar to set the stone and plaster the walls. As industrial development increased and occupations became more varied new uses were found for limestone, some depending upon the physical character of the stone, others upon its chemical composition. So varied has been the demand that the production of limestone has increased enormously. At present both limestone and lime have a wide utilization as such and in addition are employed in many manufacturing processes, and provide essential constituents for many manufactured products. Of those uses depending on its physical properties, stone for concrete aggregate, road metal, railroad ballast, riprap, asphalt filler, dimension stone, monumental stone, stucco and terrazzo, poultry grit, and filter beds demand a large tonnage. Of equal or greater importance are those uses which depend on chemical composition such as stone for agricultural purposes, for Portland and other cements, for flux stone, for refractory products, for glass and mineral wool, and for the production of many chemicals such as alkali, calcium carbide, and various insecticides. Other uses require limestone as a processing agent as in the production of wood pulp for paper, the refining of sugar, and the tanning of hides.

The value of the limestone industry in Ohio is indicated by the following taken from the Preprint on Stone from the Minerals Yearbook for 1948, compiled by D. G. Runner, Nan C. Jensen, and M. G. Downey, Bureau of Mines, United States Department of Interior, Washington D. C.

Limestone sold or used by producers in Ohio in 1948

Use	Short tons	Value
Riprap	32,100	$ 43,294
Fluxing stone	6,862,470	6,444,067
Concrete and road metal	8,064,850	9,087,524
Railroad ballast	1,351,330	1,508,684
Agriculture	2,422,460	3,835,073
Miscellaneous	1,185,190	2,336,764
Total	19,918,400	$23,055,406

The figures given above do not include the limestone necessary for the production of 10,020,198 barrels of Portland cement sold by producers in 1948 and valued at $20,496,930. The limestone required for the production of 1,936,211 short tons of lime in Ohio in 1948, as reported in the Preprint of Minerals Yearbook for that product, compiled by G. W. Josephson and F. D. Gradijan, and indicated in the following table, is likewise excluded.

Lime (quick and hydrated) sold by producers in Ohio in 1947

Use	Short tons	Value
Agricultural	47,423	$ 496,877
Building	544,483	6,546,556
Metallurgical	71,988	663,322
Paper mills	34,922	297,215
Refractory	927,715	10,697,970

Others	309,680	2,771,461
Total	1,936,211	$ 21,473,401

The total production of limestone and dolomite in Ohio for 1948 classified according to use as derived from the annual coal Report and Non-Metallic Mineral Report with Directory of Reporting Firms prepared by Marion S. Klein, Division of Labor Statistics, Department of Industrial Relations, State of Ohio, is as follows:

Use	Tons produced
Riprap	139,660
Fluxing stone	6,798,255
Concrete and road metal	7,752,425
Railroad ballast	1,544,046
Agricultural limestone	2,086,391
Dimension stone	2,400
Used in cement	3,327,081
Burned to lime	2,344,985
Refractories	1,152,272
Miscellaneous uses	941,606
Total	26,089,121

The production of limestone and dolomite by counties in Ohio in 1948 was as follows:

County	Tons Produced	County	Tons Produced
Adams	130,592	Lucas	1,112,031
Allen	481,771	Mahoning	1,397,941
Athens	37,777	Marion	578,173
Auglaize	42,364	Mercer	256,773
Belmont	17,000	Miami	610,794
Brown	6,599	Monroe	4,000
Clark	54,047	Montgomery	166,466
Clermont	17,741	Morgan	48,885
Clinton	332,011	Muskingum	774,969
Crawford	404,475	Noble	7,258
Delaware	260,695	Ottawa	4,717,573
Erie	1,006,678	Paulding	130,000
Fayette	506,104	Pike	6,265
Franklin	1,619,969	Preble	126,055
Gallia	14,123	Putnam	230,861
Greene	755,409	Ross	6,134
Guernsey	45,000	Sandusky	2,866,616
Hamilton	47,549	Seneca	754,491
Hancock	412,425	Stark	1,512,732
Hardin	395,086	Summit	550,112
Harrison	368,451	Union	149,877
Highland	266,460	Van Wert	330,863
Holmes	1,350	Vinton	19,739
Lawrence	511,571	Washington	1,483
Logan	151,515	Wood	437,559
		Wyandot	1,404,309

CHIEF PHYSIOGRAPHIC FEATURES

General Statement

The most conspicuous feature of the land surface of much of the eastern half of Ohio is the presence of innumerable hills and valleys. Physiographically this hill country represents the western continuation of the Allegheny Plateau of western Pennsylvania and West Virginia. It is separated from the Lake Plains on the north and northwest and from the Mississippi Valley Plains of western Ohio by steep outward-facing escapements. The Allegheny Plateau of eastern Ohio consists in the main of a broad upland so maturely dissected by stream erosion that the old land surface can only be visualized in the even skyline produced by the apparent accordance of the present hilltops. The rugged character of the topography has been modified to some extent in the northern and northwestern parts by the smoothing action of continental glaciation.

Escarpment

The escarpment marking the descent from the Allegheny Plateau to the Central Lowlands of western Ohio and to the Lake Plains of northwestern and northern Ohio is most noticeable southwest of Chillicothe. Extending north from the Ohio River through eastern Adams, eastern Highland, and western Ross counties the face of this escarpment rises as an irregular but veritable rock wall, sinuous in outline and notched here and there by small transverse valleys, but rising to a height of 200 to 300 feet above the general level of the lowlands to the west. Northeast of Chillicothe the face of the escarpment is less obvious as the region has been subjected to the modifying effects of continental glaciation. The outline is, in general, less regular and the rise of the surface to the east or southeast is more gentle. The escarpment, however, can be readily traced through southeastern Pickaway County, western Fairfield County, Licking County, eastern Delaware, and central Marion counties, crossing the divide in western Richland County. From southwestern Richland County the trend is to the northeast through northern Ashland, Medina, and Cuyahoga counties to the vicinity of Cleveland. From northeastern Cuyahoga County the escarpment follows the direction of the Lake Shore to the northeast but occurs a few miles to the south of it.

From Chillicothe to Cleveland and from Cleveland to the Pennsylvania line the escarpment is formed in large part by the outcropping edges of sandstones and shales of the Mississippian system aided in some areas by the underlying shales of the Upper Devonian and capped in others by resistant sandstone beds of lower Pennsylvanian age. In central and north central Ohio the rugged, highly dissected topography of the Allegheny Plateau gives way along this escarpment to lower lying till plains or moraine-dotted reaches of the Central Lowlands; in northern Ohio the transition is to the lower lying, northern sloping plains bordering the southern shores of Lake Erie.

Glaciation

The topography of the northern and western parts of the plateau area of eastern Ohio has been smoothed out to some extent by the action of the ice sheets which advanced from the north during the Pleistocene Period and covered these areas. The southern boundary of the ice advance in Ohio can be represented roughly by a line extending from near St. Clair west past Kensington in Columbiana County and through southern Stark County and central Holmes to the southeast corner of Ashland County. From the last locality the line extends in a southerly direction to northern Perry County where it turns to the southwest through central Perry, southeastern Fairfield, western Hocking, and central Ross counties, passing a few miles south of Chillicothe. North and west of this border line there is evidence of two drift sheets, an earlier or Illinoian drift and a later or Wisconsin drift. The chief area of Illinoian drift, where it occurs uncontaminated by the later and over-riding Wisconsin, occurs as a narrow belt extending from southeastern Richland County south through eastern Knox, eastern Licking, northern Perry, southeastern Fairfield, and western Hocking counties.[1] In Stark and Columbiana counties, the Wisconsin moraines are bordered on the south by a thin narrow fringe of older drift which may be of Illinoian age.

The effects of the ice sheets on the land surface covered are many and varied. The ice mass blocked old river valleys and under its influence new channels were cut. The erosive action of the ice has, in general, tended to reduce the relief and roughness of the land surface, reduce the number of rock outcrops, and by scouring off the hilltops and filling the old valleys with drift it has tended to smooth out the topography. As a result of this smoothing action depths of drift ranging up to 400 feet in thickness may be found in old preglacial and interglacial valleys whereas in areas closely adjacent bedrock may occur at the surface or be mantled by only a few feet of drift cover. By reducing the irregularities in the topography the per cent of tillable land has been increased and many suitable locations for roads, railroads, cities, villages, factory sites, and homes have been provided. Drift-filled valleys form excellent water reservoirs and water laid drift deposits of moraines and terraces provide a source of sand and gravel for various construction purposes.

Unglaciated Area

The plateau-like character of the eastern half of Ohio is best preserved in the unglaciated part. Here the old land surface is represented today by the skyline level produced by the even summits of many hills and narrow flat-topped ridges above which here and there isolated hills or groups of hills rise to somewhat greater heights like monadnocks. This skyline surface represents an old erosion surface or peneplain formed at a time when the land lay at a lower level. Since the elevation of the region the rivers and streams have so deepened their channels, lengthened their courses, and increased their tributaries that the surface has been maturely dissected. The surface resulting is hilly and uneven with a large per cent in an attitude of steep to moderate slope.

The hilltops have, in general, their lowest altitude in southern Ohio. Throughout western Washington, Athens, Meigs, Vinton, Jackson, Gallia, western Scioto, and Lawrence counties the hills rise to elevations ranging from about 900 to 1,000 feet. From this lowland area the general level of the summit elevations seem to rise in Ohio to the west, to the north, and to the northeast.[2] Near the western rim of the plateau in eastern Adams, western Pike, and western Ross counties the accordant levels have an altitude ranging from about 1,200 to 1,240 feet with occasional hilltops reaching the 1,300-foot contour. A second area of high altitude occurs over an elongated belt bordering the Ohio River in the eastern part of the State and includes Belmont, Monroe, eastern Harrison, eastern Carroll, Jefferson, and Columbiana counties. In this area the accordant levels range in altitude from about 1,200 to 1,270 feet with occasional peaks rising above the 1,350-foot level.[3] Northwest of this area the ridgetops continue at a high elevation through western Harrison, Tuscarawas, Holmes, and Coshocton counties and some peaks

[1] *White, G. W., Illinoian drift of eastern Ohio: American Journal Science, Vol. 237, pp. 161-174, 1939.*

[2] *Cole, W. Storrs, Rock resistance and peneplain expression: Jour., Geology, Vol. XLIII, pp. 1049-1062, 1935.*

[3] *Stout, Wilbur, and Lamb, G. F., Physiographic features of southeastern Ohio: Geol. Survey Ohio Reprint Series No. 1, pp. 2-3, 1939. Lamborn, R. E., Geology of Jefferson County: Geol. Survey Ohio Bull. 35, pp. 16-17, 1930.*

reach altitudes of 1,350 to 1,400 feet in Ashland, Richland, and Knox counties. Below the levels represented by the hills and ridges stream erosion has cut valleys to varying depths producing an average relief for the region of between 200 and 300 feet. A maximum relief somewhat in excess of 600 feet is attained in eastern Monroe County and in eastern Adams and western Scioto counties.

The flat or moderately rolling lands in the unglaciated part of eastern Ohio are confined for the most part to flood plains and terrace flats along existing streams, to flats along valleys abandoned by drainage changes, and to summits of divides where erosion has been less severe.

CHIEF STRUCTURAL FEATURES

General Statement

Considered in a regional sense the eastern half of Ohio forms a part of the eastern flank of the Cincinnati geanticline. From the crest of this arch which extends in Ohio from Clermont and Hamilton counties on the south to eastern Lucas and Ottawa counties on the north, the rocks dip with gentle but irregular slopes across northwestern Ohio toward the Michigan Basin on the north and across central and eastern Ohio toward the axis of the Appalachian trough on the southeast. The regional dip of the beds in the eastern half of Ohio is, therefore, in a general southeastern direction. The regular slope of the strata is broken, however, by the presence of many minor structures of small magnitude, such as noses, anticlines, synclines, domes, basins, terraces, and probably a few faults of small size. The regional structure combined with erosive effects of the weather since the final emergence of the land above sea level has been responsible for the parallel distribution of the outcrop of the various systems into which the rock series has been divided. The effect of the minor flexures in this respect is only local in extent. Of those structures occurring in the eastern half of Ohio the Cambridge Arch and Parkersburg-Lorain syncline have the greatest magnitude and largest areal expression. Other types represented by noses, terraces, domes, etc. are generally small in size and have little significance except as they have influenced the accumulation of oil and gas.

Cambridge Arch

The most prominent structure in the eastern half of Ohio is the Cambridge arch. This structure is a broad irregular arch with a crest of varying width whose axis can be represented roughly by a line extending from Newport, Washington County, to the northwest in the direction of Cleveland. It is narrowest and most strongly expressed in southern Washington County where the beds rise at least 450 feet from the syncline on the west to a structural crest which is ridge-like in contour. North of Washington County the arch becomes broader and less well defined. It attains a width of 25 to 30 miles in northern Guernsey County and southwestern Harrison County, but north of this it gradually loses its distinguishing character along its eastern boundary. The surface of the Cambridge arch is marked by much structural irregularity. In general the highest part of the arch is found along its western rim which can be represented roughly by a line extending from the Ohio River near Newport, Washington County, in a northwestern direction toward Wooster, Wayne County. Along this line the beds rise over 1,000 feet from Newport to the southern boundary of Holmes County. East of the west rim, the surface of the arch is marked by two or more small anticlinal and synclinal flexures whose axes tend to parallel the western edge of the structure. When viewed in cross section the beds rise rapidly to the western rim and then slope irregularly in an east-west direction across the top of the structure until the eastern edge is reached where the regional dip to the southeast increases. North of the glacial boundary, the number of exposures and general character of bedrock are not such as to permit detailed studies of surface structure.

Parkersburg-Lorain Syncline

The Parkersburg-Lorain syncline has been described by Lamborn as follows.[1] "From the west edge of the Cambridge arch the beds dip steeply in a westerly direction for a few miles before again rising with the regional slope toward the Cincinnati arch. A structural trough is thus formed which parallels the Cambridge arch and lies a few miles to the west of it. As the axis of this trough can be roughly represented by a line extending from Lorain, Lorain County, through Millersburg and Coshocton, to the Ohio River near Parkersburg, West Virginia, it can be appropriately called the Parkersburg-Lorain syncline. This syncline is best developed in the Marietta region where the bottom is four or five miles in width and nearly flat in an east and west direction and where the structure rises 300 feet or more to the edge of the Cambridge arch to the eastward. The trough becomes narrower and shallower to the northwest of Marietta in the east-central part of the State, and in Lorain County in the northern part it is poorly defined ....

"Along the axis of the Parkersburg-Lorain syncline the rock strata pitch 16 feet per mile in a direction S 13.75° E. from Millersburg to the Muskingum River in Washington County. The structure rises abruptly from the bottom of this trough to form a structural crest at the western edge of the Cambridge arch. In Jackson Township, Noble County, the structural rise is 220 feet in 3.5 miles in a direction N 66.5° E. Through Brookfield and Buffalo townships, Noble County, the ascent is 320 feet in 8.8 miles in a direction N. 50° E. The maximum rise at Millersburg, Holmes County, where the trough is narrow and constricted, is 160 feet in 4 miles in a direction N. 67.5° E." The rise to the northwest from the axis of the syncline is essentially the regional rise toward the Cincinnati arch modified here and there by low flexures of small magnitude or spread.

Anticlinal Noses

The regularity of the regional slope from the crest of the Cincinnati geanticline to the axis of the Parkersburg-Lorain syncline and from the eastern margin of the Cambridge arch toward the axis of the Appalachian basin is broken in the eastern half of Ohio by the presence of many low structural noses. The axes of these noses have a general northwest-southeast trend but vary irregularly in their exact compass bearing. Their length ranges in general from two to twenty miles and their height measured at right angles to the axial trend may vary from a few feet to 40 feet or more. Anticlinal noses are best known in the eastern half of Ohio over a belt extending from western Holmes County on the north to Lawrence County on the south. They are numerous from southern Lawrence County to southern Hocking County where they have an axial trend around 35° to 40° W. of N. They are likewise known in eastern Meigs County, eastern Athens County, north central Morgan County, and in Muskingum County, but their axial trend is not so uniform. Structural noses occur in good development east of the Cambridge arch in Monroe, Belmont, Jefferson, and eastern Harrison counties. One such structure extends from Barnesville, Belmont County, to the southeast in the direction of New Martinsville, West Virginia, having an axial trend of N 32° W. Prominent structural noses are also present near St. Clairsville in Belmont County and in southern Jefferson County. These structures in the latter county have an axial trend ranging from about 25° to 30° west of north. Little economic

[1] *Lamborn, R. E., Austin, C. R., Schaaf, Downs, Shales and surface clays of Ohio: Geol. Survey Ohio Bull. 39, pp. 8-10, 1938.*

importance can be attached to anticlinal noses in Ohio except as they have been effective in localizing accumulations of oil and gas at varying depths.

Dome and Basin Structures

Dome and basin-like structures are relatively unimportant elements in the structural picture of eastern Ohio. Contour inclosures of small area occur in a few localities, however, on the crest of anticlinal noses and near the bottom of synclinal flexures. The basin structures are generally elongated or oval in form with a depression of less than 40 feet and a length varying from one to five miles. Such basins are sparsely distributed over eastern Ohio. Good examples are found in Liberty Township, Washington County; Elk Township, Noble County; Marion and Stark townships, Noble County; German Township, Harrison County; and Middleton Township, Columbiana County. A notable exception to the usual occurrence is the Salineville basin located just east of Salineville in Columbiana County. Here rock deformation has led to the formation of structural basin measuring 7 1/2 miles in a northwest-southeast direction, 3 miles in a southwest-northeast direction, and showing a depression of about 150 feet.

Dome-like inclosures are not great in number but are rather widely distributed in eastern and southeastern Ohio. Although occurring in a variety of structural associations, they are most common on the crests or upper surfaces of anticlinal noses. Such dome structures are generally circular or oval in horizontal pattern, small in areal extent, and subdued in vertical expression. Structural inclosures of this type are well developed in Monroe and Millwood townships, Guernsey County; Clay Township, Tuscarawas County; Malaga and Bethel townships, Monroe County; and York Township, Belmont County. The Annapolis dome located in western Salem Township, Jefferson County, and adjoining areas on the west, is outstanding. It is oval in outline with its longer axis in a direction about N 18° E. It is about 5 1/2 miles long and about 4 miles wide and it represents an inclosure of about 75 feet.

Regional Dip

Considered in a regional sense the eastern half of Ohio forms a part of the western side of a large elongated structural basin the axis of which extends in a northeast-southwest direction through West Virginia and western Pennsylvania. Neglecting the small structural features previously described, the general inclination of the beds in the eastern half of Ohio is toward the deeper parts of this basin. The actual direction of maximum dip and the amount of departure from the horizontal shows a regional variation as measured along the outcrop at different localities. "It is found that the southern component of the dip is much greater than the eastern component in northeastern Ohio, but that the eastern component of the dip increases progressively southwest along the belt of outcrops and that in southern Ohio the eastern component is much the greater. Thus in Columbiana County the fall is 3.8 feet per mile to the east and 10.7 feet per mile to the south.[1] In Muskingum County the general slope to the east is 24 feet per mile and to the south 9 1/2 feet per mile giving a maximum dip of 24.7 feet per mile in a direction S. 66° 37' E.[2] In Vinton County the inclination to the east is 28 feet per mile and to the south 12 feet per mile giving a maximum fall of about 33 feet per mile in a direction S. 66° 48' E.[3]

[1] *Stout, Wilber, and Lamborn, R. E., Geology of Columbiana County: Geol. Survey Ohio Bull. 28, p. 50, 1924.*

[2] *Stout, Wilber, Geology of Muskingum County: Geol. Survey Ohio Bull. 21, pp. 31-33, 1918.*

[3] *Stout, Wilber, Geology of Vinton County: Geol. Survey Ohio Bull. 31, pp. 10-11, 1927.*

The regional structure on the Berea sandstone in the eastern half of Ohio follows essentially the same pattern as the structure determined from surface outcrops with some modification in the eastern part caused by the increased thickness of the Conemaugh in that area. Below the Berea sand and overlying the limestone and dolomite series outcropping western Ohio, is a thick shale series. This shale, consisting of the Bedford and Ohio shale formations, has a thickness on the outcrop ranging from 300 feet in Adams County to about 600 feet in Huron County. East of its belt of outcrops this shale thickens rapidly under cover in a direction which varies from S. 80° E in southern Ohio to about S. 60° E in northeastern Ohio. The effect of this thickening toward the axis of the Appalachian basin is to depress the underlying limestone and dolomite series to the eastward at a greater rate than is expressed by the dip of the beds at the surface. In southern Ohio the upper surface of the Devonian-Silurian limestone-dolomite series (Big Lime of the Clinton sand driller) has its maximum dip of about 53 feet per mile in a direction S. 70° E; in central Ohio the fall is about 45 feet per mile in a direction S. 75° E; and in the vicinity of Cleveland the slope is about 26 feet per mile in a direction S. 62° E. The practical effect of the high dip under cover of the Big Lime series in a general eastern direction is to narrow the belt of territory extending through the central part of the State where this stone can be mined in an economical manner by shafting.

CHAPTER II

BEDROCK FORMATIONS

GENERAL FEATURES

Based on the time of deposition, the sedimentary rock series exposed at the surface in the eastern half of Ohio falls into four great groups or systems of the Paleozoic Era of the geologic time classification. In ascending order these systems are the Devonian, Mississippian, Pennsylvanian, and Permian. The kinds of rock include all the common sedimentary types such as sandstone, conglomerate, shale, coal, clay, and limestone. The outcropping limestones, which are the chief subject of this report, are confined in their vertical distribution to the top of the Mississippian and to the various series of the Pennsylvanian and the Permian. The quarrying operations based on the various limestone formations and members are widely distributed over the area but are perhaps more numerous along the outcrops of the Pottsville and Monongahela series of the Pennsylvanian system. The basement rocks immediately underlying the rock series exposed in the eastern half of the State consist of limestones and dolomites of the Middle Devonian and of the Silurian systems. These carbonate formations have extensive outcrops in the western half of Ohio and their distribution, composition, and physical character in that area have been described in Bulletin 42 of the Geological Survey.

DEVONIAN SYSTEM

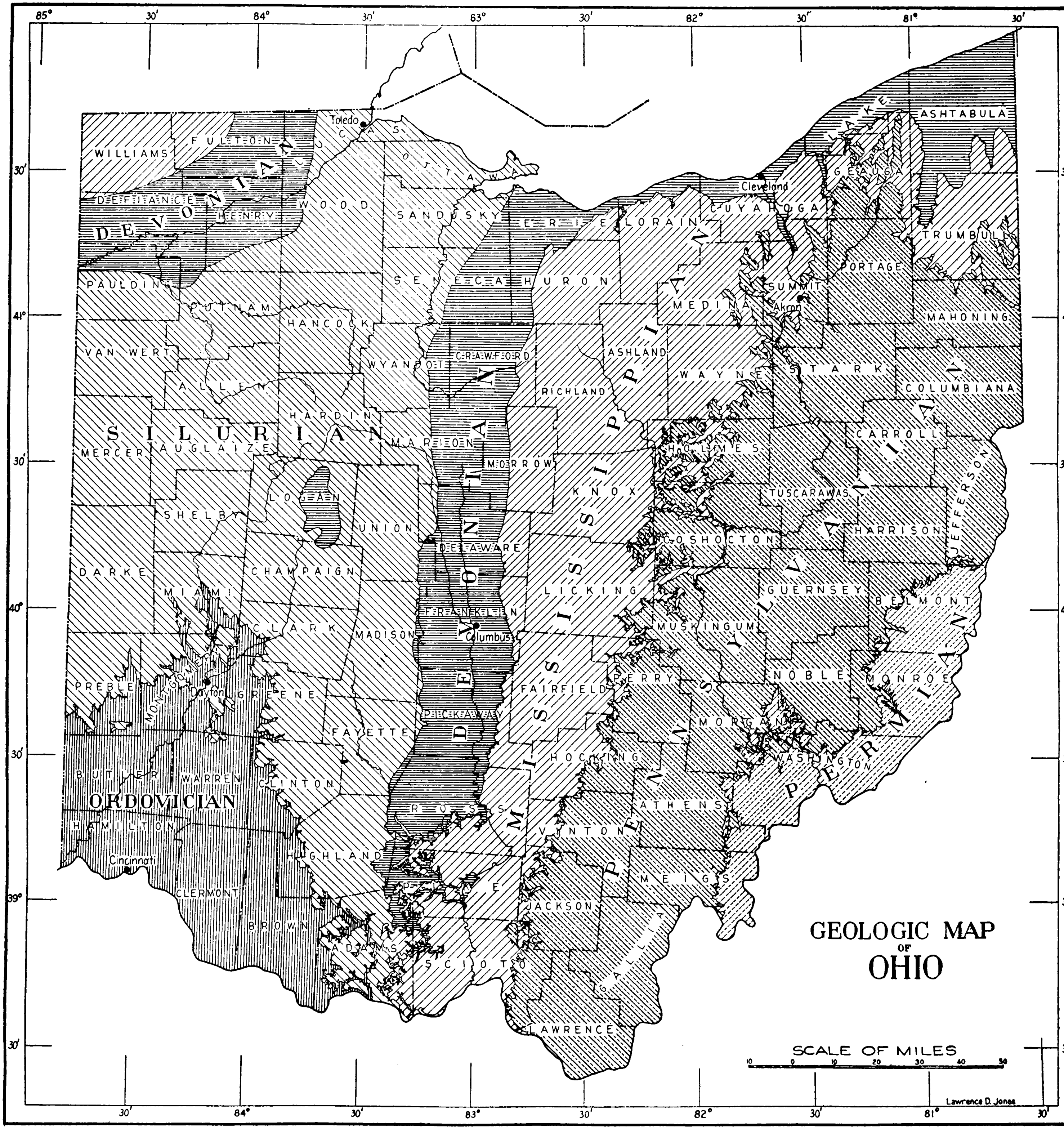
The oldest major group of Paleozoic rocks outcropping in the eastern half of Ohio belongs to the Devonian system. This group was first named the Devonian by Murchison and Sedgwick in 1839 for exposures in Devonshire, England, but soon afterward beds containing a similar fossil content were recognized at a number of localities in this country. In 1873 Dr. J. S. Newberry, State Geologist for the Second Geological Survey of Ohio, discussed the Devonian system in this State and adjoining areas to the east and south and described the general character of the beds and their distribution.[1]

The Devonian system in Ohio is made up of limestones, dolomites, and shales, with small amounts of calcareous sandstone. The total thickness of the system varies in different parts of the field of outcrop from 275 feet to about 800 feet. The lower and middle parts of the system consist chiefly of limestone, dolomitic limestone, and dolomite, the classification and lithologic characters of which have been treated in Bulletin 42. The upper part of the system which falls within the province of this report consists almost entirely of shale. The group as a whole has been subdivided into at least seven distinct parts of formations, the upper, the Ohio shale, being the only one considered in this report.

Ohio Shale

The Ohio shale which comprises the upper part of the Devonian system in Ohio outcrops over a belt varying from two to twenty miles in width and extending from Adams County on the south to Erie County on the north. From Erie County

[1] *Newberry, J. S., Geology of Ohio: Geol. Survey Ohio Vol. I, Pt. 1, pp. 65-72, 1873.*



GEOLOGIC MAP
OF
OHIO
SCALE OF MILES
10 0 10 20 30 40 50
Lawrence D. Jones
DEVONIAN
SILURIAN
ORDOVICIAN
MISSISSIPPIAN
PENNSYLVANIAN
PERMIAN
Toledo
Cleveland
Akron
Columbus
Dayton
Cincinnati
WILLIAMS
FULTON
LUCAS
OTTAWA
DEFIANCE
HENRY
WOOD
SANDUSKY
ERIE
LORAIN
CUYAHOGA
LAKE
GEAUGA
ASHTABULA
TRUMBULL
PORTAGE
SUMMIT
MEDINA
HURON
SENECA
PAULDING
PUTNAM
HANCOCK
VAN WERT
ALLEN
WYANDOT
CRAWFORD
RICHLAND
ASHLAND
WAYNE
STARK
MAHONING
COLUMBIANA
HARDIN
MARION
MORROW
KNOX
HOLMES
CARROLL
MERCER
AUGLAIZE
LOGAN
UNION
DELAWARE
TUSCARAWAS
HARRISON
JEFFERSON
SHELBY
DARKE
MIAMI
CHAMPAIGN
LICKING
COSHOCTON
GUERNSEY
BELMONT
CLARK
MADISON
FRANKLIN
MUSKINGUM
PREBLE
MONTGOMERY
GREENE
FAIRFIELD
PERRY
NOBLE
MONROE
FAYETTE
PICKAWAY
MORGAN
WASHINGTON
BUTLER
WARREN
CLINTON
HOCKING
ATHENS
HAMILTON
ROSS
VINTON
HIGHLAND
MEIGS
CLERMONT
JACKSON
BROWN
ADAMS
SCIOTO
GALLIA
LAWRENCE
85°
84°
83°
82°
81°
30'
41°
40°
39°

east to the State line the upper part of this shale formation occurs above drainage over a narrow belt bordering the southern shore of Lake Erie.

Throughout the central and southern part of the belt of outcrops, the Ohio shale is dominantly a black to dark brown, somewhat arenaceous, carbonaceous shale which splits up easily into thin slate-like slabs or pieces. Interstratified with the dark variety, particularly in the lower half of the formation, there are many thin beds of dark bluish gray somewhat arenaceous shale which seem to be discontinuous in horizontal extent. The bluish gray phase occurs in thick development in northern Ohio and from the Cuyahoga River east this type dominates on the outcrop. From Huron County east to the State line the outcrops of the Ohio shale have been divided into three parts, a lower black shale or Huron shale, a middle bluish gray bed called the Chagrin shale, and an upper black carbonaceous series named the Cleveland shale. The continuity of these divisions in central and southern Ohio is somewhat vague and uncertain.

In central and southern Ohio the base of the Ohio shale series is marked by a thin bed of soft bluish gray calcareous shale with occasional thin layers and nodules of limestone. This gray shale is quite continuous in central Ohio where it has a thickness of about 30 feet but it is patchy and irregular in occurrence in the southern part of belt of outcrops. This bed has been named the Olentangy shale.[1] In the writer's opinion it is a basal phase of the Ohio shale and will be so treated in this report.

Under cover to the east of its belt of outcrops, the Ohio shale and thin overlying Bedford shale thicken rapidly as determined by well records. The maximum rate in Ohio apparently occurs across the southern part where the isopach lines are crowded somewhat closer together and trend in a direction about N. 10°E. Along a line extending from Lancaster to eastern Washington County, representing the direction of maximum thickening, the increase in an eastern direction is at a rate of about 33.5 feet per mile. From Utica, Licking County, to southern Belmont County the rate is about 32 feet per mile; whereas from London, Huron County, to southern Columbiana County, representing the direction of maximum thickening in northern Ohio, the rate of increase is about 28 feet per mile. The expanding thickness of the Bedford-Ohio shale series under cover east of the outcrop tends to narrow the belt over which the Devonian and underlying limestone can be mined by shafting with profit to the operations.

MISSISSIPPIAN SYSTEM

Excluding the Maxville limestone which occurs at the top of the Mississippian in Ohio, this system corresponds closely with the Waverly sandstone series as that group was described by Briggs in 1838.[2] In Ohio this system of rocks "outcrop over a belt of varying width, extending from the Ohio River in Scioto County north to Huron County and then northeastward, meeting the Pennsylvania line in Trumbull and Ashtabula counties. This belt of outcrops has a width of 20 to 25 miles at its southern end, but its width increases to the north to as much as 50 miles as measured across Huron, Ashland, and Wayne counties. From this last region the belt narrows to the eastward in western Trumbull and eastern Geauga counties, the zone of outcrops being not more than 5 miles in width".[3]

Beds of Mississippian age in Ohio, with the exception of the Maxville limestone, are all of the clastic varieties, such as shale, sandstone, and conglomerate

[1] *Winchell, N. H., Geology of Delaware County: Geol. Survey Ohio Vol. 11, Pt. 1, p. 284, 1874.*

[2] *Geol. Survey Ohio First Ann. Report, pp. 79-80, 1838.*

[3] *Lamborn, R. E., Austin, C. R., and Schaaf, Downs, Shales and surface clays of Ohio: Geol. Survey Ohio Bull. 39, p. 42, 1938.*

with the shale predominating on the outcrop. The thickness of the system varies irregularly on the outcrop from as little as 300 feet in the northeastern part of Cuyahoga County[1] to as much as 1,000 feet in Ross and Vinton counties[2] and in Wayne County.[3] This variation in thickness is due in small part to the variation in thickness of sediments originally deposited but chiefly to differences in the amount of erosion following the deposition of the Mississippian strata and preceding the deposition of the Pennsylvanian beds. The Mississippian system in Ohio has been divided into six formations which are described below in ascending order.

Bedford Shale

The Bedford shale which was first named by J. S. Newberry for exposures near Bedford, Cuyahoga County,[4] lies immediately above the Ohio shale and extends upward to the Berea sandstone, meeting the latter in some localities with an uneven and irregular contact surface. Although some doubt exists as to the age relationship of the Bedford it is considered in Ohio as basal Mississippian. The Bedford shale in Ohio outcrops in a belt extending entirely across the State from Adams County on the south to Lake Erie in eastern Erie County and then east to eastern Ashtabula County. The thickness of the formation ranges in general from about 75 feet to 100 feet, but in small areas it is much less than this. It is composed for the most part of shale of a dark bluish gray and chocolate brown color but thin sandstone is locally present. Thus in the Cleveland region a fine-grained bluish sandstone, the Euclid member, occurs in the lower part of the formation.[5] Sandstone is likewise common in the upper part along the outcrops from Chillicothe south to the Ohio River. The Bedford formation contains no limestone but it is a large potential source of raw material for the ceramic industry and it has yielded some sandstone for construction purposes.

Berea Sandstone

The Berea sandstone, which is practically coextensive in distribution on the outcrop with the underlying Bedford shale, received its name from its occurrence near Berea in western Cuyahoga County,[6] where it has been quarried extensively since early times. It is everywhere on the outcrop a medium to fine-grained, gray to bluish gray quartz sandstone containing small amounts of iron, aluminum, and lime-bearing compounds. In Cuyahoga and Lorain counties, where the formation has been quarried for many years, the thickness varies irregularly from a few feet to 200 feet or more and the stone tends to be coarser grained. The formation is generally present on the outcrop over a narrow belt from southwestern Huron County south to Chillicothe where the trend is to the southwest through Ross, western Pike, and eastern Adams counties. In this field of outcrops the stone tends to be somewhat finer in texture and more regular in thickness, averaging about 30 feet. In structure the Berea sandstone is generally heavy bedded to massive with a ferruginous layer at the top and in some areas with a concretionary or contorted zone at the base. The Berea sandstone has good continuity under cover in eastern Ohio where it is widely sought by the driller and where it has yielded large quantities of oil and gas.

[1] *Prosser, Charles S., Devonian and Mississippian formations of northeastern Ohio: Geol. Survey Ohio Bull. 15, p. 194, 1912.*

[2] *Stout, Wilber, Geology of Vinton County: Geol. Survey Ohio Bull. 31, p. 43, 1927.*

[3] *Conrey, G. W., Geology of Wayne County: Geol. Survey Ohio Bull. 24, pp. 49-50, 1921.*

[4] *Newberry, J. S., Report of Progress in 1869, Pt. 1, Geol. Survey Ohio, p. 22, 1871.*

[5] *Prosser, Charles S., op cit., p. 51, 1912.*

[6] *Newberry, J. S., op. cit., p. 22.*

Sunbury Shale

The Sunbury shale, known in early reports of the Survey as the Waverly Black slate and the Berea shale and later named by L. E. Hicks for exposures near Sunbury, Delaware County,[1] is a thin but persistent formation immediately overlying the Berea sandstone. As characteristically developed on the outcrops, the Sunbury is a black to brownish black shale which is high in carbonaceous material and which resembles the black portion of the Ohio shale in all its lithologic characteristics. The thickness of the formation in Ohio varies from 15 feet to 40 feet. East of the outcrop the Sunbury is widely recognized by the driller to whom it is generally known as the "coffee shale."

Cuyahoga Formation

The term Cuyahoga was first applied in a formational sense by J. S. Newberry to dove-colored shales and fine blue sandstones overlying the Berea sandstone in the vicinity of Cleveland in the northern part of the State.[2] The Waverly series above the Berea in central Ohio was later subdivided by Hicks in ascending order into the Sunbury shale, Raccoon shale, Black Hand conglomerate, and Licking shale.[3] Prosser in 1905 limited the Cuyahoga formation to include those beds occurring above the Sunbury shale and below the Black Hand.[4] Later after a detailed study of the Mississippian in central and southern Ohio, Hyde extended the formation upward to include the lower 50 to 150 feet of the Black Hand formation and placed the top of the Cuyahoga formation at the base of the Berne conglomerate member.[5] In 1921 after a study of the Mississippian formations in Ross and Pike counties, Hyde correlated the Berne member with the Buena Vista, a thin sandstone member which occurs a few feet above the Sunbury shale along the western edge of Scioto and Pike counties.[6]

As thus limited the Cuyahoga formation in Ohio varies from a few feet to 600 feet or more in thickness. Gray clay shales with occasional thin sandstones make up a large part of this formation. The upper part in some areas however, is composed of massive sandstone, the Black Hand member. This sandstone is exceptionally well developed on the outcrop east of Newark in Licking County and along the Hocking Valley in southern Fairfield County and in northern Hocking County. Scattered quarries have operated in Cuyahoga sandstones at various times in eastern Franklin County and in Licking and Fairfield counties for the production of stone for building and other construction purposes.

In northern Ohio sandstone belonging to the Cuyahoga formation has been quarried near Mansfield in Richland County and near Warren in Trumbull County.

Limestone does not occur in the Cuyahoga in Ohio and further detail in regard to the formation is therefore unnecessary in this report.

Logan Formation

The term Logan was first applied by E. B. Andrews about 1870 to a group of

[1] *Hicks, L. E., The Waverly group in central Ohio: Am. Jour. Sci., 3rd Series, Vol. 16, pp. 216-220, 1878.*

[2] *Newberry, J. S., op. cit, p. 22, 1871.*

[3] *Hicks, L. E., op. cit., pp. 216-20.*

[4] *Prosser, Charles S. , Revised nomenclature of Ohio Geological formations: Geol. Survey Ohio Bull. 7, p. 2, 1905.*

[5] *Hyde, J.E., Stratigraphy of the Waverly formations of central and southern Ohio: Jour. Geol. Vol. 23, pp. 657, 677, 678, 1915; Geology of Vinton County: Geol. Survey Ohio Bull. 31, p 51. 1927.*

[6] *Hyde, J. E., Geology of Camp Sherman Quadrangle, Geol. Survey Ohio Bull. 23, pp. 151-153, 1921.*

fine-grained sandstones, 133 1/2 feet in thickness, occurring in Hocking County between the base of the coal measures and the Waverly conglomerate.[1] As later defined by Hyde in 1915, the Logan formation includes the Logan sandstone of Andrews and extends down to the bottom of the Berne conglomerate, a thin bed occurring in the Black Hand formation of some former classification.[2] Hyde also divided the Logan into four members, namely the Berne, Byer, Allensville, and Vinton.

The Logan formation in Ohio can be traced on the outcrop without the loss of essential characteristics from the Ohio River in Scioto County to northern Wayne County. Northeast of Wayne County this formation is generally wanting in Ohio. In the area of outcrops the known thickness of the Logan ranges from about 150 feet to 275 feet. It is made up entirely of the clastic type of sediments. The Berne and Allensville members are composed chiefly of coarse-grained sandstone and conglomerates, whereas fine-grained sandstone characterizes the Byer and sandstones and shales mark the horizon of the Vinton member.

Maxville Limestone

The top formation of the Mississippian system in Ohio is the Maxville limestone, so named by Newberry for exposures occurring near Maxville, Monday Creek Township, Perry County.[3] Unlike the other formations of the Mississippian in Ohio the Maxville is very local in its occurrence on the outcrop. Post Mississippian erosion removed much of the formation before the deposition of the superjacent Pennsylvanian leaving more or less isolated remnants of a once more continuous deposit. As first suggested by Morse [4] and later described by Stout, [5] the base of the Maxville may also rest on an old erosion surface, which is probably of slight vertical expression. Remnants of the Maxville limestone are confined on the outcrop to a number of scattered places located over a belt extending from southwestern Muskingum County to the Ohio River and including small areas in Muskingum, Perry, Hocking, Vinton, Jackson, and Scioto counties. The outcrops having the largest areal extent occur from Fultonham, Muskingum County, to Logan, Hocking County. Under cover to the east of the outcrops, remnants of the Maxville limestone have been penetrated in wells over more or less separated areas of varying size in Lawrence, Gallia, Meigs, northeastern Vinton, Athens, Morgan, eastern Perry, and southern Muskingum counties and also in parts of Monroe and eastern Washington counties. One of the largest and thickest of these deposits underlies parts of Harrison, Brush Creek, southern Newton, and Clay townships, Muskingum County. The Maxville limestone is not known to be encountered in wells drilled north of an east-west line coinciding with the northern boundary of Harrison County.

The characteristics of the Maxville on the outcrop in Ohio have been described by Morse as follows:[6]

"In the Northern Area along Jonathan Creek and Kents Run, the Maxville limestone is divided into a lower and an upper half by a thin zone near the middle of the stratum. This zone, the shale nodular zone of the report, is made up of small nodules or nodular-like layers of limestone, which alternate with shales, both of which are very fossiliferous. The lower zone consists of massive clayey limestone the bedding planes of which are irregular and very indistinct. In the upper zone the stratification is the conspicuous feature, because the shaly partings found between

[1] *Andrews, E. B., Report of Progress in 1869: Geol. Survey Ohio Pt. II, p. 79. 1871.*

[2] *Hyde, J. E., Op. cit. pp. 657, 677-678, 1915.*

[3] *Andrews, E. B., op. cit., p. 83, 1871.*

[4] *Morse, W. C., The Maxville limestone: Geol. Survey Ohio Bull 13, pp. 67-68, 1910.*

[5] *Stout, Wilber, Geology of Muskingum County: Geol. Survey Ohio Bull. 21, pp. 34-35, 1918.*

[6] *Morse, W. C., op. cit., p. 100.*

the thin or medium layers of limestone are commonly weathered away, thus permitting each layer to project apparently independently from the face of the cliff. This zone in many places is fairly fossiliferous, while the lower one is generally but sparingly so.

"At nearly every place in the Northern Area where the lower contact of the Maxville is exposed, pre-Pottsville erosion has removed all or nearly all of the upper zone, so that the complete thickness of the formation is difficult to obtain. The shale-nodular zone enables one, however, to trace other zones from place to place, and by combining the measurements of these the thickness of the lower and upper halves is secured. The thickness of the lower half was found to be a little greater than twenty-five feet. The maximum thickness of the upper zone is at a point opposite the Fultonham depot and at one nearly a mile below, where this half is, respectively, about fifteen to twenty-two feet. This gives us a thickness of nearly forty-three and fifty feet for the stratum the maximum thickness in the Northern Area, and one which agrees very closely with that of records of nearby wells."

The upper part of the Maxville limestone in the Fultonham area is a limestone of good purity whereas the lower part is highly dolomitic in composition.

PENNSYLVANIAN SYSTEM

In the early writings dealing with the geology of Pennsylvania, the coal bearing series of rocks were divided into five groups on the basis of the presence or absence of workable coal beds. In ascending order these groups were named as follows: Seral conglomerate, Lower Coal measures, Lower Barren measures, Upper Coal measures, and Upper Barren measures.[1] After a study of the plant fossils overlying the Waynesburg coal, which marked the top of the Upper Coal measures, Fontaine and White concluded in 1880 that the Upper Barren measures were Permian in age.[2] Accepting these conclusions H. S. William included the four remaining groups into the Pennsylvanian series in 1891.[3] In more recent years the Pennsylvanian has been elevated in general usage to the rank of system.

Beds belonging to the Pennsylvanian system outcrop over an elongated belt of varying width in the eastern half of Ohio extending from the Ohio River in Scioto, Lawrence, Gallia, and Meigs counties on the south to the State line in Trumbull, Mahoning, Columbiana, Jefferson, and Belmont counties on the east. Thirty-seven counties occur wholly or in part in this belt including, in addition to those already mentioned, the following: Geauga, Portage, Summit, Medina, Cuyahoga, Stark, Wayne, Holmes, Tuscarawas, Carroll, Knox, Coshocton, Harrison, Ashland, Licking, Muskingum, Guernsey, Monroe, Noble, Morgan, Perry, Fairfield, Hocking, Athens, Washington, Vinton, Pike, and Jackson. The total area over which strata of Pennsylvanian age outcrop is about 10,464 square miles or about one-fourth of the area of the State.

The bedrocks composing the Pennsylvanian system are all of the sedimentary type. In the order of their increasing abundance on the outcrop they consist of iron ore, conglomerate, coal, clay, limestone, and sandstone and shale. The average total thickness of the system in Ohio is about 1,115 feet. The limestone beds, which are the chief interest in this report, occur at twenty-seven different horizons which are widely spaced throughout the system. Limestones of both

[1] *Rogers, H. D., Geology of Pennsylvania, Vol. II, pp. 16-20, 1858.*

[2] *Fontaine, Wm. C., White, I. C., The Permian or Upper carboniferous flora of West Virginia and southwest Pennsylvania: Second Geol. Survey Pa. Rep't pp. 105-120, 1880.*

[3] *Williams, H. S. Correlation papers, Devonian and Carboniferous, pp. 105-120, U.S. Geol. Survey Bull. 80, pp. 81-82, 108, 1891.*

marine and of fresh or brackish water origin are represented. Those of marine origin are comparatively thin and are confined for the most part to the lower half of the system. The limestone members of fresh or brackish water origin reach their best development in the upper half of the system where they often consist of several layers of limestone separated by thin zones of calcareous shale. The Pennsylvanian system has been subdivided into four large groups or series and each of these in turn into many smaller subdivisions or members. A brief description of the different series and the limestone members of each is given in the following pages.

Pottsville Series

The lowest division of the coal measures in Pennsylvania was first named the Seral conglomerate by R. D. Rogers in 1858.[1] Later, in 1877, J. P. Lesley in describing the succession of coal-bearing strata in western Pennsylvania named this basal division the Pottsville conglomerate and defined it as extending from the Mauch Chunk red shales below to the base of the Lower Productive Coal measures.[2]

In Ohio the Pottsville series is everywhere present as the lowest subdivision of the Pennsylvanian. It lies unconformably on the Maxville limestone or in its absence on the underlying sandstones and shales of the Waverly group. The thickness of this series on the outcrop varies according to Stout from 175 feet to 400 feet,[3] but averages about 255 feet. It is made up of several beds of sandstone, shale, clay, coal, limestone, and iron ore with a bed of conglomerate, the Sharon, prominently developed at the base of the series in some localities. Outcrops of the Pottsville occur in 23 counties in Ohio including parts or all of Trumbull, Mahoning, Columbiana, Geauga, Portage, Stark, Summit, Medina, Wayne, Holmes, Tuscarawas, Knox, Coshocton, Muskingum, Licking, Perry, Fairfield, Hocking, Vinton, Jackson, Scioto, Lawrence, and Pike. Four limestone members occur in the Pottsville in Ohio all of which are of marine origin and all of which are found closely overlying clay or coal beds. These limestones are generally thin and inconspicuous elements but their wide distribution give them stratigraphic importance. Locally one of these members is of no mean importance as a source of limestone.

Lowellville Limestone

The Lowellville, first named by G. W. Lamb in 1910 for exposures near Lowellville, Mahoning County, is the lowest limestone horizon in the Pottsville in Ohio.[4] In 1918 Stout described the Poverty Run limestone as closely overlying the Vandusen coal in Muskingum County.[5] On the basis of fossil content Morningstar later correlated the Poverty Run with the Lowellville limestone as defined by Lamb.[6]

The Lowellville limestone is local in its development in Ohio as outcrops have been recognized only near Lowellville, Mahoning County; in Hopwell, Falls, and Madison townships, Muskingum County; and in Washington Township, Coshocton County. It is generally a dark, compact, fossiliferous impure limestone which is not known to exceed one foot in thickness and is generally much thinner. In Muskingum County the position of this member is about 55 feet below the Lower Mercer limestone.

[1] *Rogers, H. D., Geology of Pennsylvania: Vol. I, p. 109, 1858.*

[2] *Second Geol. Survey Pa. Rep't. HHH, p. 23, 1877.*

[3] *Stout, Wilbur, and others, Coal formation clays of Ohio: Geol. Survey Ohio Bull. 26, p. 104, 1923.*

[4] *Lamb, G. W., Pennsylvanian limestone of northeastern Ohio below the Lower Kittanning coal: Ohio Naturalist, Vol. 10, pp. 128, 129, 1910.*

[5] *Geol. Survey Ohio, Bull. 21, p. 65, 1918.*

[6] *Morningstar, Helen, Pottsville fauna of Ohio: Geol. Survey Ohio Bull. 25, p. 28, 1922.*

Boggs Member

The Boggs member of the Pottsville is variable in composition as it may consist of iron ore, limestone, flint, and fossiliferous shale. The iron ore phase was first called the Boggs ore for the name of the land owner on whose property it was first opened for development in Bloom Township, Scioto County.[1] In dealing with the geology of eastern Scioto County, Stout described the Boggs ore as closely overlying the Lower Mercer coal.[2] Later he used the term Boggs member for the limestone, flint, ore, and fossiliferous shale occurring close above the Lower Mercer coal in Muskingum County.[3] In general the Boggs is an unimportant member in Ohio for its lime content. In Scioto, Lawrence, and Jackson counties it is chiefly an iron ore which was formerly mined and utilized in the charcoal furnaces. Northward in northwestern Muskingum County the Boggs is composed chiefly of fossiliferous limestone and flint rarely exceeding 2 feet in thickness. North of Muskingum County the Boggs member is of doubtful occurrence on the outcrop in Ohio. The position of the Boggs in Muskingum County is approximately 20 feet below the Lower Mercer limestone.

Lower Mercer Limestone

The Lower Mercer limestone, formerly called the Blue limestone and Zoar limestone in early reports on the geology of Ohio, is the most prominent and widely distributed limestone member of the Pottsville series in Ohio and is also widespread on the outcrop in northwestern Pennsylvania. In the early writings of the Geological Survey of Pennsylvania this bed was called the Mercer limestone.[4] Later White considered Lower Mercer to be a more appropriate name for this member[5] and as a result the latter term has come into general use in both Ohio and Pennsylvania.

In Ohio the Lower Mercer limestone is persistent along its line of outcrop extending through Mahoning, Columbiana, Portage, Summit, Stark, Wayne, Tuscarawas, Holmes, Coshocton, Muskingum, Licking, Hocking, Perry, Vinton, and northern Jackson counties. In southern Jackson County and in Scioto County this limestone is generally wanting. The thickness of this limestone in eastern and northeastern Ohio varies on the outcrop from a few inches to 10 feet or so but the usual measurements fall between 6 inches and 4 feet with an average of about 2 feet. In its usual development the Lower Mercer is a hard tough, dark blue to black limestone which may occur as a single layer, two or more layers separated by bedding planes only, or layers of limestone with thin shales interstratified. In general the limestone is conspicuously fossiliferous with the fossils generally of a lighter color than the surrounding matrix. Nodules or layers of flint interbedded in the limestone are generally wanting. In some areas the member is more or less closely overlain by the Lower Mercer ore and is invariably closely underlain by the Middle Mercer coal and clay. The position of the Lower Mercer limestone in Ohio varies in general from about 65 feet to 90 feet below the base of the Brookville coal which marks the top of the Pottsville series.

The Lower Mercer limestone has been quarried at a number of localities in northeastern Ohio and has been utilized for various purposes, chief of which is for agricultural limestone. Its importance is overshadowed in some areas, however, by the Putnam Hill limestone which is often thicker in development, is quarried with equal ease, and yields a stone of equal or greater purity.

1 ..ton, *Edward, The iron ores of Ohio: Geol. Survey Ohio Vol. V, p. 421, 1884.*

2 *Stout, Wilber, Geology of Southern Ohio: Geol. Survey Ohio Bull. 20, p. 567, 1916.*

3 *Stout, Wilber, Geology of Muskingum County: Geol. Survey Ohio Bull. 21, pp. 70-75, 1918.*

4 *Rogers, H. D., Geology of Pennsylvania: Vol. II, Pt. 1, pp. 474-477, 1858.*

5 *White, I. C., Geology of Lawrence County: Second Geol. Survey Pa. Rep't. QQ, p. 57, 1879.*

Upper Mercer Limestone

From 15 to 40 feet above the Lower Mercer, another limestone occurs which is widespread on the outcrop and which Rogers named the Mahoning limestone from exposures along the Mahoning Valley in western Pennsylvania.[1] In his writings for the Second Geological Survey of Pennsylvania, White discarded the term Mahoning of Rogers, renamed the member the Upper Mercer, and placed the type locality at Mercer, Mercer County.[2] In 1884 Orton accepted White's usage of this term for Ohio[3] although he had previously referred in reports to the Upper Mercer as the Gore limestone.[4]

The outcrops of the Upper Mercer limestone horizon in Ohio have essentially the same areal distribution as that of the Lower Mercer previously described. In Scioto, Lawrence, and Jackson counties, the limestone is seldom present although its position is closely marked by the overlying Upper Mercer ore. North of Jackson County, in Vinton, Perry, Hocking, Licking, Muskingum, Coshocton, Tuscarawas, Holmes, Wayne, Stark, Summit, Portage, Mahoning, and Columbiana counties, the Upper Mercer limestone member tends to be more regular in occurrence on the outcrop. It is quite variable in composition and physical character, however, and over many small areas it is wanting. As generally developed the member is composed of hard, compact, dense-textured limestone of a dark bluish gray to gray black color with varying amounts of black flint. The flint may be present as nodular masses scattered throughout the limestone but a common mode of occurrence is a basal flinty limestone capped by a flint layer of irregular thickness. Like the Lower Mercer, the Upper Mercer limestone and flint are everywhere fossiliferous. The thickness of the member varies from a few inches to nearly 10 feet with an average a little in excess of one foot. In Coshocton County, where the thickest known outcrops occur, the Upper Mercer consists of two or more beds of flinty limestone, separated by thin beds of shale. Due to its generally highly siliceous character the Upper Mercer is of trifling economic importance for uses where a limestone of high purity is desired. It has been utilized in a small way in areas near the outcrop for road stone and for ornamental stone.

Allegheny Series

Much confusion arising from limited observation and differences in terminology has attended the early classification of the coal-bearing series of Pennsylvania and Ohio. In his early writings on the geology of Pennsylvania, Rogers included strata of Allegheny age in the Older Coal Measures of his classification.[5] As the beds of this group were early explored and developed along the Allegheny River, they also become widely known as the Allegheny Group or Allegheny River Series. One of the early writers to describe this group was J. J. Stevenson who in 1873 defined the Allegheny River Series as extending from the great conglomerate to the base of the Mahoning sandstone.[6] In Ohio this series was formerly termed the Lower Coal Measures or the Lower Productive Measures. As now used in this State the Allegheny includes all the strata from the base of the Brookville or No. 4 coal to the top of the Upper Freeport or No. 7 coal.

[1] *Rogers, H. D., op. cit., p. 417.*

[2] *White, I. C., op. cit, pp. 57-58.*

[3] *Orton, Edward, The stratigraphic order of the lower coal measures of Ohio: Geol. Survey Ohio Vol. V, p. 15, 1884.*

[4] *Orton, Edward, Supplemental report on the geology of the Hanging Rock district: Geol. Survey Ohio Vol. III, p. 898, 1878.*

[5] *Rogers, H. D., op. cit., pp. 16, 477, 1858.*

[6] *Stevenson, J. J., Notes on the geology of West Virginia: Am. Philos. Soc. Trans., Vol. 15, p. 16, 1873.*

As thus defined the Allegheny series has a thickness on the outcrop in Ohio which varies from about 175 to 250 feet but averages a little over 200 feet. [1] It is everywhere underlain by the Pottsville and overlain by the Conemaugh without evidence of a marked diastropic break at either contact. This series outcrops over an area of about 2,200 square miles including all or parts of the following counties: Lawrence, Scioto, Jackson, Gallia, Vinton, Hocking, western Athens, Perry, Muskingum, Coshocton, Guernsey, Tuscarawas, Holmes, Harrison, Carroll, Stark, Portage, Mahoning, Columbiana, and Jefferson. The beds comprising the Allegheny are of the types usually associated with the coal-bearing series. In addition to coals, clays, and shales, which are widely known and highly rated as sources of fuel and raw materials for the ceramic industry, six limestone members are also found in this series. Three of these limestone members are of marine origin and occur closely overlying coal beds and three are of the fresh or brackish water type associated with the coal measure clays. Two of the marine limestones have been quarried extensively along the outcrop yielding much stone of high purity for agricultural purposes, for road stone, for Portland cement and for furnace flux.

Putnam Hill Limestone

The stratigraphic position of the Putnam Hill limestone is close above the Brookville coal and it is, therefore, the lowest limestone member of the Allegheny. This limestone, which is confined in its occurrence to Ohio, was first described and its importance noted by Foster in 1838 [2] and was later named the Putnam Hill by E. B. Andrews in 1869 [3] for exposures at Putnam Hill in Zanesville, Muskingum County, where it is well exposed. From the type locality the limestone extends in good development on the outcrop to the south in southwestern Muskingum and in Perry counties, and to the north and northeast through Muskingum, Licking, Coshocton, Holmes, Wayne, Tuscarawas, and Stark counties. It is thin or wanting on the outcrop in Hocking, northern Vinton, Lawrence, Scioto, and western Gallia counties and is generally thin and shaly in southern Vinton and in Jackson counties. [4] The Putnam Hill limestone is of doubtful occurrence northeast of Stark County in southern Portage County and in Mahoning and Columbiana counties.

In the chief field of exposures in east central Ohio the Putnam Hill varies in thickness from a few inches to about 13 feet with a mean of about 3 feet. The limestone is hard and compact and generally has a dense texture. The color is usually gray to bluish gray of a lighter shade than the Mercer limestones which occur lower in the system. Nodules and zones of flint or chert are present in places in the Putnam Hill member but such impurities are not as prevalent as in the Upper Mercer, and the color is generally darker than that of the chert occurring in the overlying Vanport member. Fossils of marine forms of life are numerous and widely distributed in the limestone and in the shales overlying it, and in some localities they are found in abundance.

The Putnam Hill limestone has been quarried along the outcrop and utilized for human needs in the community since the early settlement of the country. Much current local demand exists for a limestone to neutralize organic soil acidity, and for this purpose the Putnam Hill is well adapted as the content of calcium and magnesium carbonates in the stone is high. This member is being quarried in a small way at a number of places in Coshocton, Holmes, Wayne, and Stark counties.

[1] *Stout, Wilber, Generalized section of the rocks of Ohio, Geol. Survey of Ohio Inf. Cir. No. 4.*

[2] *Foster, J. W., Geol. Survey Ohio Second An. Rep't, p. 93, 1838.*

[3] *Andrews, E. B., Geol. Survey Ohio Rep't. Prog. 1869, Pt. II, p. 88, 1871.*

[4] *Stout, Wilber, Geology of Vinton County: Geol. Survey Ohio Bull. 31, p. 170, 1927.*

Vanport Limestone

The Vanport limestone was first named by White in 1878 for its occurrence at Vanport, Beaver County, Pennsylvania.[1] Previous to 1878, this limestone was generally known as the Ferriferous because of its close association in northeastern Pennsylvania,[2] and in southern Ohio[3] with an economically important iron ore. In Ohio the horizon of this limestone outcrops entirely across the eastern half of the State from Lawrence County on the south to Mahoning and Columbiana counties on the east. The deposits of limestone of good thickness and quality are confined for the most part to southern Vinton, Jackson, Lawrence, and eastern Scioto counties in southern Ohio and to Tuscarawas, eastern Stark, and Mahoning counties in northeastern Ohio. In intervening areas along the outcrop, the member is generally thin, erratic in character, and patchy in distribution. In the southern area the limestone is persistent on the outcrop where it occurs in massive to heavy-bedded development varying in thickness from 1 to 10 feet with a usual measurement of about 4 to 6 feet. The stone is generally gray to light brown in color, finely crystalline to dense in texture, and fossiliferous in character. Nodular flint is of common occurrence in the top part of the member. The limestone is closely overlain by the Ferriferous iron ore and underlain by the Clarion coal from which it is often separated by a few feet of shale.

In the northern area the Vanport limestone is local in distribution in northwestern Tuscarawas County, is exposed at only a few places in Stark County, but occurs in good development near Youngstown, Mahoning County, where it has been quarried for many years. The limestone has a brownish to bluish gray color, is dense to finely crystalline in texture, and generally occurs in layers one to 12 inches in thickness, some of which are nodular in character. The maximum development occurs in eastern Mahoning County where the limestone measures about 20 feet in thickness.

The Vanport limestone has been quarried for many years in southern and eastern Ohio and utilized extensively for furnace flux, and for Portland cement, road stone, and agricultural limestone.

Hamden Member

Few members of the Pennsylvanian series are more variable in character than the Hamden. It may be represented on the outcrop from place to place by iron ore, dark fossiliferous shale, nodular limestone, regularly bedded limestone, or by any combination of these forms. First known as the Hamden ore for its occurrence near Hamden, Vinton County,[4] the use of the term was later extended to include the limestone phase which occurs on the ore horizon in Muskingum County.[5] The Hamden member lacks persistence on the outcrop but deposits of either ore, shale, or limestone are widespread for they occur in every county from Jefferson and Columbiana on the east to northern Jackson County on the south. Fossiliferous shale with nodular iron ore is of more common occurrence than limestone. Where present the limestone is generally dense and hard and of a dark gray to nearly black color. It usually occurs as nodular or boulder-like masses embedded in shale or basal part of Oak Hill clay although in a few localities it is a well bedded limestone. The thickness of the limestone varies from a few inches to a maximum of 3 or 4 feet. The thickest deposits known to occur on the Hamden horizon are found in the north central part of Muskingum County.

[1] *White, I. C., The Beaver River district of western Pennsylvania: Second Geol. Survey Pa. Rep't. Q, pp. 60-63, 1878.*

[2] *Rodgers, H. D., op. cit., p. 491.*

[3] *Andrews, E. B., Geol. Survey Ohio Rep't. Prog., 1870, Pt. II, p. 61, 1871.*

[4] *Stout, Wilber, Geology of Southern Ohio: Geol. Survey Ohio Bull. 20, p. 252, 1916.*

[5] *Stout, Wilber, Geology of Muskingum County: Geol. Survey Ohio Bull. 21, p. 173, 1918.*

Salem Limestone

The Salem is a thin limestone member of the Allegheny which has not been positively identified outside of Columbiana County, Ohio Its interest as a limestone horizon is, therefore, stratigraphic rather than economic. Near Salem, for which place it was named by Stout in 1924,[1] the bed is a light bluish to brownish gray dense-textured limestone, somewhat ferruginous in composition, having a thickness of about 8 inches. In places the member is a calcareous iron ore. As the thickness is generally less than 1 foot, the Salem member has no importance as a source of limestone.

Lower Freeport Limestone

In early reports on the geology of Pennsylvania the Lower Freeport limestone was called the Middle Freeport in Cambria and Somerset counties[2] and the Butler limestone in Beaver County.[3] Later, at Lesley's suggestion, White changed the name of this limestone to Lower Freeport in his report on Lawrence County,[4] a term which has been generally accepted.

In Ohio the Lower Freeport merits little attention as a potential resource for limestone. Although the horizon outcrops entirely across the State from Lawrence and Gallia counties to Columbiana and Jefferson counties, the limestone is local in occurrence and is invariably thin and of mediocre quality. The stone is generally gray to bluish gray in color and dense and compact in structure. The fossils that are present are limited to the fresh or brackish water types. Impurities in the form of clay and iron carbonate are generally present in varying amounts. The mode of occurrence of the Lower Freeport is distinctly different from those limestones previously described in that the member generally consists of nodules and lens-like masses of varying size occurring at the base of or embedded in the Lower Freeport clay. Where present on the outcrop the limestone varies in thickness from a few inches to a maximum of 4 or 5 feet. It is probably best developed in Ohio over small areas in Columbiana County where it was formerly utilized for the production of natural cement and to a small extent for agricultural limestone.[5]

Upper Freeport Limestone

From 3 to 12 feet below the base of the Upper Freeport coal there is an irregular bed of limestone which Rogers called the Freeport limestone[6] in northwestern Pennsylvania and which Newberry apparently described as the White limestone in Mahoning County, Ohio.[7] In his report on Lawrence County, Pennsylvania, White, at the suggestion of Lesley, renamed the Butler limestone, which underlies the Lower Freeport coal and which was not recognized by Rogers, the Lower Freeport and called the Freeport limestone of Rogers, the Upper Freeport.[8] This terminology has been generally accepted in writings dealing with the geology of the coal measures in Pennsylvania, West Virginia, and Ohio.

[1] *Stout, Wilber, and Lamborn, R. E., Geology of Columbiana County: Geol. Survey Ohio Bull. 28, p. 146, 1924.*

[2] *Platt, F. and W. G., Cambria and Somerset district: Second Geol. Survey Pa. Rep't. H H, p. XXVIII, 1877.*

[3] *White, I. C., Beaver River district: Second Geol. Survey Pa. Rep't. Q, p. 49, 1878.*

[4] *White, I. C., The Geology of Lawrence County: Second Geol. Survey Pa. Rep't. QQ, p. 31, 1879.*

[5] *Stout, Wilber, and Lamborn, R. E., Geology of Columbiana County: Geol. Survey Ohio Bull. 28, pp. 190-195, 1924.*

[6] *Rogers, H. D., Geology of Pennsylvania, Vol. II, pp. 476, 492, 493, 1858.*

[7] *Newberry, J. S., Report on the Geology of Mahoning County: Geol. Survey Ohio, Vol. III, pp. 797-798, 1878.*

[8] *White, I. C., op. cit.,*

In Ohio the Upper Freeport limestone is present in some degree of development in every county where its outcrops are due from Lawrence and western Gallia on the south to southern Mahoning, Columbiana, and Jefferson counties on the east. In general it is very poorly represented in Lawrence, Gallia, Meigs, Jackson, and Vinton counties, is thin and local in occurrence in Muskingum County, and is rarely present on the outcrop in Coshocton, Guernsey, Tuscarawas, Carroll, and Jefferson counties. It probably reaches its best known state of development in Ohio in Columbiana County, where it tends to be more continuous on the outcrop although still subject to many wants, and where the thickness reaches a maximum of about 20 feet.[1]

The lithologic characteristics and general mode of occurrence of the Upper Freeport limestone is quite similar to that of the Lower Freeport previously described. Where in scanty development the member generally consists of nodular masses of limestone embedded in the Upper Freeport clay. Better development is marked by one or more layers of stone located either in the clay bed or at its base. The limestone is generally of a gray to bluish gray color and it is often argillaceous and more or less highly ferruginous in composition. In places the limestone shows a brecciated structure Fossils of fresh or brackish water types of life are of common occurrence. Where present in a bedded form, the average thickness of the Lower Freeport limestone will probably fall between 1 and 2 feet.

Conemaugh Series

The third major subdivision of the Pennsylvanian system of rocks in the Appalachian Basin in ascending order consists of thick beds of sandstone and shale with a few thin coals, clays, and limestones. Unlike the underlying and overlying series it contains no coal beds of exceptional thickness or broad extent. For this reason the group was called the Lower Barren Measures by Rogers in 1858 and was defined in his tables of classification as extending from the Mahoning sandstone upward to the base of the Upper Coal measures.[2] In describing this series Rogers states: "This lower barren group has for its inferior limit the top of the Upper Freeport coal and for its superior boundary the bottom of the great Pittsburgh bed."[3]

In 1875, Franklin Platt applied the name Conemaugh to the beds of the Lower Barren group including the Mahoning sandstone because of its good development along the Conemaugh River in western Pennsylvania.[4] This name has come into general use and the series is now known in Ohio as the Conemaugh.

The outcrops of the Conemaugh series in Ohio occur as a broad belt varying in width from 15 to 40 miles extending across the southeastern part of the State from Columbiana, Jefferson, and northern Belmont counties on the east to Lawrence and Gallia counties on the south. In addition to those counties already mentioned outcrops of the Conemaugh occur in Jackson, Meigs, Vinton, Athens, Hocking, Perry, Morgan, Muskingum, Noble, Guernsey, Coshocton, Tuscarawas, Harrison, Stark, and Carroll counties. In Ohio the Conemaugh has its least thickness in Lawrence County where it measures about 350 feet. From this area the series tends to expand to the northeast along the belt of outcrops reaching its maximum depth in this State of about 518 feet in Jefferson County.

In addition to the sandstones and shales which are the predominating types in the Conemaugh, no less than eleven thin coal beds and thirteen limestone horizons

[1] *Stout, Wilber, and Lamborn, R. E., op. cit., pp. 221-222.*

[2] *Rogers, H. G., Geology of Pennsylvania: Vol. II, p. 16, 1858.*

[3] *op. cit., p. 19.*

[4] *Platt, Franklin, Clearfield and Jefferson district: Second Geol. Survey Pa. Rep't. H, p. 8, 1875.*

have been recognized on the outcrop of this series in Ohio. The limestones and the coal beds are closely associated in their stratigraphic field relations. Five of the limestone members, namely the Brush Creek, Cambridge, Portersville, Ames, and Skelley, contain a marine fauna and are found closely overlying definite coal members. The Mahoning, Bloomfield, Ewing, Gaysport, Elk Lick, Clarksburg, Summerfield, and Pittsburgh limestone members contain a fresh or brackish water fauna and are generally associated with calcareous clays and argillaceous calcareous shales found close below coal horizons. The marine limestones, being the more continuous and widespread, were laid down in open shallow seas whereas the irregular character and distribution of the fresh water limestones suggest that they were deposited in shallow lakes or swamps of restricted area. The limestone members of the Conemaugh are briefly described in ascending order in the following pages.

Mahoning Limestone

The Mahoning limestone, which was first named by I. C. White in 1891,[1] is a thin discontinuous member found closely associated with the underclays of the Mahoning coal, the lowest coal bed of the Conemaugh series. In its lithologic and faunal characters the Mahoning limestone much resembles the Lower Freeport and Upper Freeport limestones previously described. It consists for the most part of nodules and lime-like layers of gray to bluish gray, somewhat ferruginous limestone occurring in or at the base of the Mahoning or Thornton clay. Its usual position is from about 1 to 10 feet below the Mahoning coal and from about 15 to 50 feet above the Upper Freeport coal. The Mahoning limestone horizon outcrops over a broad belt-like area in Ohio extending from Columbiana and Jefferson counties on the east to Lawrence and Gallia counties on the south but the limestone is wanting over large areas and where present it is generally thin and poorly developed. Thin nodular limestone can probably be found on the Mahoning horizon in every county where its horizon outcrops but the economic importance of the bed as a source for limestone is trifling.

Brush Creek Member

The Brush Creek, named by I. C. White in 1878 for exposures along Brush Creek in Cranberry Township, Beaver County, Pennsylvania,[2] is a member which has a wide distribution on the outcrop but varies much from place to place in physical character and chemical composition. In Ohio outcrops of the Brush Creek member occur over a narrow belt extending entirely across southeastern Ohio from Columbiana and Jefferson counties on the east to eastern Lawrence and western Gallia counties on the south. Local wants of the member in this belt are generally accompanied by an excessive thickness of the Buffalo sandstone the base of which has transgressed the Brush Creek horizon. In Columbiana, Jefferson, Carroll, Harrison, Tuscarawas, Guernsey, and Muskingum counties the Brush Creek consists for the most part of black sandy fossiliferous shale and bluish gray fossiliferous shale which varies in thickness from 1 to 20 feet. In this area irregular lens-like layers and boulder-like masses of hard black dense fossiliferous limestone are of common occurrence embedded in the lower part of these shales. In Morgan, Perry, Athens, Meigs, Vinton, Gallia, and Lawrence counties the Brush Creek, having a maximum thickness of 25 to 30 feet, is generally made up of two limestones separated by a few feet of shale. The upper limestone is the better developed of the two and it is probably the one represented on the outcrop north of Morgan County. It consists of several layers of stone each ranging from 1 inch to 1 foot or more in thickness, separated by shale partings. The limestone is generally hard and compact and usually has a bluish gray color. Impurities in

[1] *White, I. C., Stratigraphy of the bituminous coal fields of Pennsylvania, Ohio, and West Virginia: U. S. Geol. Survey Bull. 65, pp. 96-97, 1891.*

[2] *White, I. C., Beaver River district: Second Geol. Survey Pa. Rep't. Q, p. 34, 1878.*

the form of iron oxides and chert are abundant. Fossil remains of marine forms of life are present in both the limestone and the shale.

The stratigraphic position of the Brush Creek limestone member with respect to persistent overlying and underlying elements is somewhat variable across the outcrop in Ohio. In Lawrence County the base of the Brush Creek lies on an average from 80 to 90 feet above the Upper Freeport coal and from 20 to 30 feet below the Cambridge limestone. [1] In Muskingum County these intervals are 40 feet to the Cambridge limestone and 57 feet to the Upper Freeport, [2] whereas in Jefferson County the intervals are 59 feet and 116 feet to the Cambridge and Upper Freeport respectively.

Limestone on the Brush Creek horizon occurring in sufficient thickness to warrant quarry operations is limited in general to the outcrop south of Muskingum County. In this area the highly siliceous character of the stone renders it unfit for uses where a high calcium carbonate content is required. It has been quarried at a few places in Gallia and eastern Lawrence counties and utilized for construction of road beds for which purpose it seems satisfactory.

Cambridge Limestone

The Cambridge limestone was first named by E. B. Andrews for its occurrence near Cambridge, Ohio, where the member is exceptionally well developed on the outcrop. [3] South of the Cambridge area the member is generally present along its horizon of outcrop with a few wants and with variable thickness and lithologic characteristics, through Muskingum, eastern Perry, western Morgan, Athens, western Meigs, eastern Vinton, western Gallia, and eastern Lawrence counties to the Ohio River. Northeast of Guernsey County outcrops occur in southern Tuscarawas, northwestern Harrison, Carroll, northern Jefferson, and Columbiana counties in Ohio and also in parts of northwestern Pennsylvania where it is generally known as the Pine Creek limestone. [4] The intervals from the Cambridge to other well known members of the Conemaugh varies from place to place along the outcrop in Ohio. In Lawrence and Gallia counties this member is generally found from 20 to 30 feet above the well known Brush Creek beds and about 80 feet below the Ames limestone. Both intervals tend to expand along the outcrops to the northeast, but this expansion is more rapid northeast of Muskingum County. In Guernsey County the member lies about 50 feet above the base of the Brush Creek marine beds and about 106 feet on an average below the Ames limestone. In Jefferson County these intervals are on an average 59 feet to the base of the Brush Creek and 139 to the Ames limestone.

The Cambridge is extremely variable in chemical composition and general physical character. At a few scattered localities it is a bluish gray somewhat nodular fossiliferous limestone of fair quality. Over large areas, however, it is represented by either a thin nodular iron ore, a thin nodular, highly ferruginous limestone, a highly siliceous limestone, or nodular limestone embedded in fossiliferous shale. The member reaches its thickest known development in Ohio in western Guernsey County and in northeastern Muskingum County where it is a highly siliceous limestone having a maximum depth of about 12 feet. In this area a number of quarries have operated in the Cambridge member to supply stone for road construction. This member also has good quality and continuity in western Gallia County where it measures from 1 to 4 feet in thickness and where it has been quarried for road stone and for agricultural limestone. [5]

[1] *Stout, Wilber, Geology of Southern Ohio: Geol. Survey Ohio, Bull. 20, p. 414, 1916.*

[2] *Stout, Wilber, Geology of Muskingum County: Geol. Survey Ohio Bull. 21, p. 234, 1918.*

[3] *Andrews, E. B., Geology of Athens County; Geol. Survey Ohio Vol. I, p. 262, 1873.*

[4] *White, I. C., Beaver River district: Second Geol. Survey Pa. Rep't. Q, p. 32, 1878.*

[5] *Stout, Wilber, Geology of southern Ohio: Geol. Survey Ohio Bull. 20, pp. 655-656, 1916.*

Bloomfield Limestone

The Bloomfield, named by Stout for its occurrence near Bloomfield, Highland Township, Muskingum County, [1] is a thin gray limestone which lies from 2 to 20 feet above the Cambridge limestone and from 2 to 6 feet below the Anderson coal. It is apparently local in distribution as the persistent deposits are confined to Salem and Highland townships, Muskingum County, and as the member has not been positively identified beyond the limits of that county. As the thickness of the member at known occurrences varies from a few inches to about 2 feet 6 inches and averages about 1 foot, it has slight importance beyond its stratigraphic interest.

Portersville Member

From 12 to 30 feet above the Cambridge limestone and immediately overlying the Anderson coal is the Portersville fossiliferous horizon first named by Condit for exposures near Portersville, Perry County, Ohio. [2] Where this member is best developed it consists of 2 or 3 feet of black fossiliferous shale above which is a thin nodular limestone, a few inches in thickness. Elsewhere on the outcrop it may be represented by only a few inches of fossiliferous shale or be a concretionary limonitic layer. Outcrops of the Portersville have been recognized at many places over the belt of outcrops from Guernsey County south to the Ohio River in Gallia County. The Portersville member has no importance as a source of limestone.

Ewing Limestone

The Ewing limestone was first named by Orton in 1878 for exposures near Ewing Site (now Jacksonville) in the Sunday Creek Valley, Trumble Township, Athens County. [3] Although it is never an important member as a source of limestone, the Ewing occurs widely distributed on the outcrop from Lawrence County to Jefferson County. The member consists for the most part of nodules or discontinuous nodular layers of gray to bluish gray dense-textured somewhat ferruginous limestone embedded in the clays underlying the Barton coal. In places the limestone shows brecciation and elsewhere it may be so highly ferruginous that it approaches an iron ore in composition. The thickness of the limestone and associated calcareous clays may range from a few inches to 10 feet or more. The Ewing is more continuously represented on the outcrop in Noble, Guernsey, and Harrison counties and probably has its poorest development in Jefferson and southeastern Columbiana counties. The Ewing has slight importance as a source of limestone although the float along the outcrop in some localities is sufficiently heavy to permit the use of the stone for local needs.

Ames Limestone

The Ames limestone, early known as the Green Fossiliferous limestone and as the Crinoidal limestone by geologists in Pennsylvania and West Virginia, was first given a locality name by J. S. Newberry in 1873 for exposures near Amesville, Ames Township, Athens County, Ohio. [4] In general, the Ames limestone is the most easily recognized and the most widely distributed of the limestones of the Conemaugh. In Ohio outcrops occur in every county over a belt extending from eastern Lawrence County to southern Columbiana County and includes parts of Gallia, Meigs, Athens, Morgan, Perry, Noble, Muskingum, Guernsey, Harrison, Tuscarawas, Carroll, and Jefferson counties. The stone shows good continuity over the outcrops although in a few localities it is wanting through lack of deposi-

[1] *Stout, Wilber, The Geology of Muskingum County: Geol. Survey Ohio Bull. 21, pp. 242-243, 1918.*

[2] *Condit, D. D. Conemaugh, formation in Ohio: Geol. Survey Ohio Bull. 17, pp. 41-42, 1912.*

[3] *Orton, Edward, Geology of the Hanging Rock region: Geol. Survey Ohio Vol. III, p. 890, 1878.*

[4] *Newberry, J. S., Geology of Athens County: Geol. Survey Ohio Vol. I, p. 271, 1873.*

tion and in many others through the transgression of its horizons by Morgantown sandstone. In general the limestone is a dark bluish to greenish gray color and it usually occurs as a single stratum a few inches to 3 feet or so in thickness. Where a greater thickness is found the member is generally represented by two or more layers separated by bedding planes or by thin partings of calcareous shale. The stone is hard and tough and, being more resistant to weathering than the associated shale, breaks up into rectangular blocks which are strewn over the surface below the place of outcrop. On fracture it shows a more or less crystalline, granular texture due to the cleavage surfaces of calcite. The color is generally gray, pink, or greenish in tint although in places it becomes reddish brown and highly ferruginous. Fossils of marine forms of life are abundant, the most conspicuous being the button-like segments of crinoid stems which protude in relief on a weathered surface and give the stone the peculiar crinoidal appearance for which it is well known. Where present on the outcrop in Ohio the thickness of the Ames varies from a few inches to a maximum of about 15 feet, but the usual measurements are from 1 to 4 feet. It reaches its thickest known development in Ohio in western Jefferson County. The stratigraphic position of the Ames limestone within the Conemaugh can probably best be described by referring it to the widely known Pittsburgh coal which caps the series. In Gallia County the vertical interval from the Ames to the Pittsburgh as recorded by Condit is about 155 feet.[1] This interval continues fairly constant as far north as Muskingum County. It expands rapidly, however, through Guernsey, Harrison, and Carroll counties and reaches a maximum of about 215 feet in Jefferson County.

Aside from its importance as a stratigraphic key horizon, the Ames limestone is also worthy of notice for its economic possibilities. Where the member is thick enough to warrant exploitation its physical properties are generally adequate to meet the requirements for road construction and repair, for foundation stone, and for uses of a like nature. In Guernsey, Harrison, Jefferson, Carroll, and Columbiana counties in the northern part of the belt of outcrops, chemical analyses show the calcium and magnesium carbonate content of the stone to range from 85 to over 90 per cent. The Ames limestone has been quarried at a number of localities in this area for road stone and has been utilized in a less degree for agricultural limestone. It was formerly quarried in the northern part of Jefferson County and used for flux stone in the old charcoal furnace at Irondale.[2]

Gaysport Limestone

The term Gaysport has been applied by Stout to a thin fossiliferous member consisting of impure limestone and calcareous sandstone, occurring a few feet above the Ames limestone near Gaysport, Blue Rock Township, Muskingum County, Ohio.[3] The known occurrence of this member is confined to southeastern Muskingum County and northern Morgan County. In Muskingum County it has a thickness ranging from 3 inches to 2 feet 6 inches and it lies on an average about 16 feet above the Ames limestone. No importance can be attached to the Gaysport member as a source for limestone.

Skelley Member

The Skelley is a thin member which occurs in general from 15 to 35 feet above the Ames limestone and which has been recognized in Ohio in Morgan, Noble, Monroe, Muskingum, Guernsey, Harrison, Carroll, and Jefferson counties. At Skelley Station, Wayne Township, Jefferson County, for which locality it was first

[1] *Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17, p. 34, 1912.*

[2] *Stout, Wilber, and Lamborn, R. E., Geology of Columbiana County: Geol. Survey Ohio Bull. 28, p. 351, 1924.*

[3] *Stout, Wilbur, Geology of Muskingum County: Geol. Survey Ohio Bull. 21, pp. 258-259, 1918.*

named by Condit in 1912,[1] the Skelley is a limestone varying from 1 to 2 feet in thickness which overlies the Duquesne coal. Here is much resembles the Ames limestone which at this locality lies about 18 feet below it. Elsewhere in the county the Skelley may be represented by ferruginous limestone, by dark fossiliferous shale, or by nodular limestone embedded in shale. In Guernsey, Muskingum, Noble, Monroe, and Morgan counties the Duquesne coal has not been recognized and the Skelley consists for the most part of a few thin nodular layers of limestone embedded in calcareous shale. Interest attached to the Skelley member must be chiefly stratigraphic or paleontologic in nature as its economic importance as a source of limestone is trifling.

Elk Lick Limestone

In the report on Somerset County, Pennsylvania, Messrs. Platt described a limestone lying a few feet below the Elk Lick coal which they called the Elk Lick limestone.[2] Although this coal and limestone are both well developed in northern West Virginia and adjacent parts of Pennsylvania, they have not been recognized on the outcrop in Ohio except over small areas in Jefferson County. Here the limestone is of the typical fresh water type consisting of nodular masses or thin lens-like layers embedded in the underclay of the Elk Lick coal. Where present on the outcrop the maximum thickness does not exceed 2 feet and the average is much less than this. The position of the member is on an average about 25 feet above the Skelley limestone and 48 feet below the Clarksburg coal. Due to its local occurrence and thin development the Elk Lick has no importance as a source of limestone.

Clarksburg Limestone

The Clarksburg limestone, named by I. C. White for exposures near Clarksburg, Harrison County, West Virginia, [3] is poorly represented on the outcrop in Ohio. Where present it consists for the most part of nodules or one or more nodular layers of limestone occurring in the clays or marly calcareous shales immediately underlying the Clarksburg coal horizon. It is similar lithologically to the Elk Lick limestone in being a dense bluish gray somewhat impure limestone and like it is of fresh or brackish water origin Although outcrops of its horizon extend from Gallia and Lawrence counties to Jefferson County, the Clarksburg limestone has not been positively identified except in Athens, Meigs, and Jefferson counties. In these areas the limestone is local in occurrence ranging in thickness from a few inches to a foot or so. Little economic importance can be attached to it as a source for limestone.

Summerfield Limestone

From 50 to 75 feet below the Pittsburgh coal a limestone of the fresh or brackish water type is present in some localities which Condit has named the Summerfield limestone for its occurrence near Summerfield, Noble County, Ohio.[4] In Pennsylvania and West Virginia this member is generally known as the Lower Pittsburgh limestone, -a name given to it by I. C. White in 1891.[5]

In Ohio the Summerfield is best represented on the outcrop from Morgan County north through Muskingum, Guernsey, Noble, Belmont, Harrison, and

[1] *Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull, 17, p. 27, 1912.*

[2] *Platt, F. and W. G., Cambria and Somerset districts: Second Geol. Survey Pa. Rep't HHH, p. 60 1877.*

[3] *White, I. C., Stratigraphy of bituminous coal fields of Pennsylvania, Ohio, and West Virginia U. S. Geol. Survey Bull. 65, p. 88, 1891.*

[4] *Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17, p. 23, 1912.*

[5] *White, I. C., op. cit., p. 87.*

Jefferson counties. Where typically developed the member consists of several layers or irregular beds ranging from a few inches to 3 feet in thickness, separated from each other by thin zones of shale or by bedding planes only. The limestone is generally gray to light buff in color, dense in texture, and often quite pure in composition. Brecciation is often present in basal layers and others generally show minute veins of calcite. In Noble County and in eastern Guernsey County, where the member contains little shale and where it may reach a thickness of 6 to 8 feet, the stone is quarried at a few localities and is utilized for road stone and for agricultural limestone, for which purposes both its physical properties and its chemical composition render it suitable. On the outcrop south of Morgan County the Summerfield is either represented by a little nodular limestone embedded in calcareous shale or is totally wanting in the section.

Pittsburgh Limestone

The Pittsburgh limestone, first named by H. D. Rogers for its occurrence "immediately below the Pittsburgh coal seam" [1] in western Pennsylvania and generally known as the Upper Pittsburgh limestone in West Virginia, [2] is widely distributed across southeastern Ohio. Outcrops of this member have been identified in Lawrence, Gallia, Meigs, Athens, Morgan, Muskingum, Noble, Guernsey, Belmont, Harrison, Jefferson, Carroll, and Monroe counties although it is by no means continuous in these areas. The member may consist of a single irregular layer of limestone separated from the base of the Pittsburgh coal by a thin bed of clay, nodular limestone embedded in clay or clay shales, or several layers of limestone interstratified with calcareous, argillaceous shale. The thickness of the limestone and associated beds ranges from 2 feet to over 20 feet but the usual thickness is 4 or 5 feet. The limestone is best developed on the outcrop from Athens County northeast to Belmont County, where the limestone seems more regularly bedded and where the thickness may reach 10 feet. Concerning the characteristics of the Pittsburgh limestone Condit writes as follows: [3]

"The limestone varies widely in lithologic and chemical character. It is usually somewhat dolomitic and has some silica and clayey material. A buff or brownish color is common in the more ferruginous beds, while others show a bluish, or almost black color, due to finely disseminated carbonaceous material. The rock has rarely any trace of crystalline texture and is more often entirely amorphous, and only shows its crystalline character when viewed in thin sections..... There are almost invariably a few fossils present, all of which are minute forms, generally regarded as freshwater......"

In that part of the field where the Pittsburgh limestone is thickest and most continuous, namely northeast of Athens County, other limestones of similar character lying a short distance above the Pittsburgh coal occur in even thicker developments. As a result the Pittsburgh limestone has been but slightly used. At many localities where it can be stripped with economy, the physical and chemical properties of the stone are such that it can be used for road stone and probably for agricultural limestone. Known quarries in the Pittsburgh limestone are confined to Belmont and Harrison counties.

Monongahela Series

Above the Conemaugh or Lower Barren measures there is a group of strata containing several valuable coal beds which Rogers first described in western

1. *Rogers, H. D., Geology of Pennsylvania, Vol. II, p. 634, 1858.*

2. *White, I. C., op. cit., p. 87, W. Va. Geol. Survey Vol II, p. 245, 1903.*

3. *Condit, D. D., op. cit., p. 21.*

Pennsylvania as the Upper or Newer coal measures.[1] As defined by him this group of rocks included the strata from the base of the Pittsburgh coal to the top of the Waynesburg coal. Because of the excellent development of its coals along the Monongahela River in Pennsylvania, Rogers later named this series the Monongahela, a term which has come into general use.

In Ohio the Monongahela series outcrops over an area of 1,213 square miles. The field of outcrops embraces an irregular belt extending from Jefferson and Belmont to Gallia and Lawrence counties and includes, in addition to those already mentioned, parts of Harrison, Monroe, Guernsey, Noble, Washington, Morgan, Muskingum, Athens, and Meigs counties. The thickness of the series is remarkably uniform in these counties. According to Stout the maximum variation is from 220 to 270 feet with an average not far from 250 feet.[2]

The rocks of the Monongahela series consist chiefly of sandstone, shale, coal, limestone, and clay. In general conglomerates are wanting and the iron ore, so prominently developed in the Pottsville and lower Allegheny, are present only as small nodules in shale. Seven coal beds occur in this series, four of which are of widespread importance as sources of fuel. The limestone members are unusually well developed in the Monongahela in Ohio where they comprise, on an average, approximately 50 per cent of the total thickness of the series. Stout describes these limestones as follows;[3]

"The limestones are all of fresh water origin as is indicated by the small fauna of gastropods, ostracods, and other diminutive forms of shell life. These rocks vary in color from light to dark gray, in texture from soft chalky to dense smooth, and in composition from very shaly to quite pure. The beds show the irregularity in thickness and the lenticularity in form usually attendant with fresh water deposits of calcareous matter. These limestones are always interbedded with shale and frequently give way laterally to such material." In ascending order of their occurrence the limestone members of the Monongahela in Ohio are Redstone, Fishpot, Benwood, Arnoldsburg, Uniontown, and Waynesburg.

Redstone Limestone

The position of the Redstone limestone where present in the section is only a few feet below the Redstone coal. Because of this close association this limestone was first named the Redstone by Messrs. Platt of the Second Geological Survey of Pennsylvania in 1877.[4] In Ohio the outcrops of the Redstone limestone horizon extends across southeastern part of the State from Jefferson to eastern Lawrence counties. The limestone is best developed, however, in Jefferson, southeastern Harrison, western Belmont, eastern Guernsey, and western Monroe counties. In and southwest of Muskingum and Noble counties the Redstone limestone horizon is occupied chiefly by shale and shaly sandstone although some thin limestone is present on the outcrop in Meigs, Gallia, and eastern Lawrence counties.

In the field of best development the Redstone limestone varies greatly in thickness. The top of the member is generally separated from the overlying Redstone coal by 2 or 3 feet of calcareous clay or clay shale whereas the base may extend nearly to the Pittsburgh coal, a maximum vertical distance of about 40 feet, or be separated from the coal by a variable thickness of sandy shale or sandstone. The member generally consists of several layers of gray to dark bluish gray,

[1] *Rogers, H. D., Geology of Pennsylvania: Vol. II, p. 19, 1858.*

[2] *Stout, Wilbur, The Monongahela series in eastern Ohio: Proc. W. Va., Acad. Sci. Vol. 3, pp. 118-133, 1929.*

[3] *Stout, Wilber, op. cit., p. 119, 1929.*

[4] *Platt, F. and W. G., Cambria and Somerset district: Second Geol. Survey Pa. Rep't. HHH, p. 62, 1877.*

dense-textured limestone separated by thin clay or calcareous shale partings. The limestone layers range in thickness from a few inches to as much as 6 feet. The stone is tough and hard and is generally siliceous and dolomitic in composition. It has been quarried at a few places along the outcrop in Belmont and Harrison counties to supply local demands for road stone and for agricultural lime. The composition of the Redstone is illustrated by Samples No. 363 and 364.

Fishpot Limestone

In the interval between the Redstone limestone and the Meigs Creek coal there is a fresh water limestone which is the most persistent and regularly bedded of the Monongahela limestones outcropping in Ohio. It was first named the Fishpot limestone by J. J. Stevenson for exposure along Fishpot River in southwestern Washington County, Pennsylvania,[1] and is the same as the Sewickley limestone of some later reports on West Virginia. In Ohio the Fishpot limestone is present in every county along the outcrop of its horizon from Jefferson and Belmont on the east to Lawrence and Gallia on the south. The member tends to be local in occurrence and variable in thickness in Jefferson County, and at many localities in Meigs, Gallia, and Lawrence counties its horizons is occupied by sandstone. It is probably best developed in Belmont, Noble, Guernsey, Monroe, Washington, Athens, Morgan, and Muskingum counties where the limestone tends to be regularly bedded and where, according to Stout, the average thickness is not far from 31 feet.[2] In this field it has been worked extensively in many small quarries along the outcrop and utilized for road stone and for limestone for agricultural purposes.

Where best developed along the outcrop the Fishpot is a regularly bedded limestone, the layers being separated by thin shale partings. In the upper part of the member, the part quarried most extensively, the limestone layers range in thickness from 2 or 3 inches to 3 feet, whereas the intercalated shale beds generally range from a fraction of an inch to 6 inches in thickness. From 5 to 8 feet below the top of the member there is a prominent break marked by 2 feet or so of shale with a few thin limestone layers. Locally in Athens, Morgan, Washington, and southern Noble counties thin sandy layers occur in this break. The color of the stone ranges from a light chocolate brown to a dark bluish gray. Some beds show lamination and others are mottled in light and dark shades of bluish gray. The stone is generally dense in texture and compact in structure and generally tends to be somewhat brittle. On breaking it is reduced to angular pieces with smooth surfaces and sharp edges exhibiting a fracture similar to flint. In composition the Fishpot limestone is generally somewhat impure. Varying amounts of silica, ferrous carbonate, and clay material are present. The per cent of magnesium carbonate is also variable and in places the limestone is decidedly dolomitic.

Benwood Limestone

The limestone beds occurring between the Uniontown and Sewickley coals in southwestern Pennsylvania were first named the Great Limestone by Rogers in reports of the First Geological Survey of Pennsylvania. Later the part of the Great Limestone lying close below the Uniontown coal was named the Uniontown limestone by Stevenson.[3] For the lower part of this group, White proposed the name Benwood for exposures near Benwood, Marshall County, West Virginia. Still later Grimsley defined the top of the Benwood limestone member as the base of the Fulton Green shale,[4] a thin shale member which in eastern Ohio occurs about midway between the Sewickley and Uniontown coals. The Benwood member

[1] *Stevenson, J. J., Greene and Washington district: Second Geol. Survey Pa. Rep't. K, p. 67, 1876.*

[2] *Stout, Wilber, The Monongahela Series in eastern Ohio: W. Va., Acad. Sci. Proc. Vol. 3, p. 126, 1929.*

[3] *Stevenson, J. J., Greene and Washington district: Second Geol. Survey Pa. Rep't. K, pp. 63-64, 1876.*

[4] *Grimsley, G. P., Rep't. Ohio, Brooke, and Hancock counties: W. Va. Geol. Survey, p. 92, 1906.*

as thus defined includes the limestone between the Sewickley coal and the Fulton Green shale.

Limestone deposits on the Benwood horizon are widely distributed on the outcrop across eastern and southeastern Ohio. The member tends to be more clearly defined and uniformly developed in the northern part of the field in Jefferson, Belmont, eastern Harrison, and eastern Monroe counties where the underlying Upper Sewickley sandstone is generally wanting and where the overlying Fulton Green shale is generally present on the outcrop. Southwest of Monroe and Washington counties the Fulton Green shale is either wanting or its horizon is represented by thin lenticular sandstone. In many areas the Benwood can not be distinguished from the overlying Uniontown limestone. The thickness of the Benwood limestone in Ohio, according to Stout, varies from about 52 feet to 65 feet with an average of 59 feet.[1]

The Benwood limestone in Ohio consists of a series of limestone strata separated by calcareous shale partings. The limestone tends to be more prominent than the shale in the northern part of the belt of outcrops whereas the shale exceeds the limestone in the southern part. The lithologic character of the stone is similar to other limestones of the Monongahela. It tends to be dense, hard, and brittle yielding angular pieces on fracture similar in form and general contour to that of flint. The stone on fresh exposure is generally a light to dark bluish gray which on weathering bleaches to a gray or light buff. The chemical properties of this stone are somewhat variable. In the better parts of the deposit the stone contains a high per cent of carbonates but a dolomitic character is expected. The limestone has been worked at a few places for road stone and for agricultural uses.

Arnoldsburg Limestone

In Jefferson County, Ohio, and in the northwestern part of West Virginia, that part of the Great Limestone which overlies the Fulton Green shale is divided into two parts by a sandstone (Arnoldsburg) or shale. To the lower limestone which lies close above the Fulton Green shale the name Arnoldsburg has been given by D. B. Reger for its close association with the overlying Arnoldsburg sandstone.

In the southern part of Jefferson County the Arnoldsburg consists of several layers of gray to buff limestone interbedded with buff calcareous clay shale. The average total thickness of the beds is about 13 feet, more than one-half of which is calcareous shale. The limestone member is overlain by about 30 feet of gray arenaceous shale. Along the outcrop to the south and southwest of Jefferson County this shale bed becomes less distinct, probably grading to argillaceous shale with thin limestone and rendering the Arnoldsburg limestone no longer distinguishable from the Uniontown. In Richland Township, Belmont County, Switzerland Township, Monroe County, and Stock Township, Noble County, thin sandstone lenses interbedded with shale may represent this shale interval.[2]

Slight economic importance can be attached to the Arnoldsburg limestone in Jefferson County where it can be distinguished from the Uniontown, as the stone is thin and always ferruginous and argillaceous in composition.

Uniontown Limestone

The Uniontown limestone, first named by J. J. Stevenson for its close association with the Uniontown coal,[3] is widely distributed on the outcrop in Ohio which extends from Jefferson County to Gallia County. The upper limit of this limestone member is clearly defined by the Uniontown coal to which the top of limestone may

[1] *Stout, Wilber, op. cit., pp. 129-130, 1929.*

[2] *Stout, Wilber, op. cit., pp. 130-131, 1929.*

[3] *Stevenson, J. J., Greene and Washington districts: Geol. Survey Pa. Rep't. K, pp. 63-64, 1876.*

closely approach or be separated by thin calcareous shale or sandstone. The lower limit of the member is not clearly separated from the underlying Arnoldsburg or Benwood as the shales representing the Arnoldsburg sandstone horizon are not clearly defined south of Jefferson County and as the Fulton Green shale likewise disappears from the section southwest of Monroe County. According to Stout there is no justification for separating the Uniontown limestone from the underlying Benwood over much of the outcrop area in eastern Ohio.

Stout describes the Uniontown limestone in Ohio as follows:[1] "Like the Benwood the Uniontown limestone member consists of a series of thin to massive limestones separated by thin to thick shale partings, some places one and some places the other material predominating. On the whole the deposits are more shale than limestone. The Uniontown member is less calcareous than the Benwood but is much the same physically and structurally. The shale partings are light gray in color and clay-like in texture. In some localities where shale predominates the weathered material is highly colored red, pink, or brownish red, thus much resembling some of the deposits in the Conemaugh series. The limestone is light to dark gray on fresh fractures but is nearly white varying to shades of buff on weathered surfaces...... The most massive layers of limestone lie either near the top of the member or in the basal portion just above the Fulton Green shale."

The Uniontown limestone member has yielded stone at a few small quarries along the outcrop for road purposes and for agricultural lime.

Waynesburg Limestone

Stout describes the Waynesburg limestone in Ohio as follows:[2]

"The Waynesburg limestone named by Stevenson for deposits in Washington and Green counties, Pennsylvania, lies directly or closely below the Little Waynesburg coal and from 10 to 25 feet below the Waynesburg coal. The material is of fresh water origin and the deposits, where typically developed, consist of several layers of light-colored limestone separated by partings of light gray shale. The thickness of the member is from four to five feet. Limestone is prominent on this horizon only in Belmont and Monroe counties. Elsewhere the lateral representative is a grainy, light to drab calcareous clay, bearing some marly limestone in the basal portion."

PERMIAN SYSTEM

The upper productive coal measures are overlain in parts of the Appalachian Basin by a younger series of rocks which was known in early writings as the Upper Barren group by Rogers, the Upper Barren Measures by Orton and Stevenson, and the Dunkard Creek series by White.[3] In 1876 J. J. Stevenson in his report on Greene and Washington counties, Pennsylvania, subdivided this series into two parts: an upper or Greene County group and a lower or Washington County group.[4] A few years later Fontaine and White made a study of the plant fossils near the base of the series in Pennsylvania and West Virginia. They concluded that the beds above the Waynesburg coal belonged to the Permian system, a name introduced by

[1] *Stout, Wilber, op. cit., p. 130, 1929.*

[2] *Stout, Wilber, op. cit. p. 132, 1929.*

[3] *White, I. C., Stratigraphy of the bituminous coal fields of Pennsylvania, Ohio, and West Virginia: U. S. Geol. Survey Bull. 65, p. 20, 1891.*

[4] *Stevenson, J. J., Greene and Washington districts: Second Geol. Survey Pa. Rep't. K, pp. 34-37, 1876.*

Murchison in 1841 for a rock series overlying the coal measures in Permian, Russia. [1]

In Ohio the beds of Permian age outcrop over an elongated area comprising about 1,830 square miles located along the Ohio River in the southeastern part of the State. The field of exposures extends from southern Jefferson to eastern Meigs County and includes parts of Jefferson and Monroe, Noble, Washington, Morgan, Athens, and Meigs counties. The maximum total thickness of the system exposed is in excess of 600 feet. The character of the Permian beds in Ohio is described by Stauffer and Schroyer as follows: [2]

"The Dunkard is a most variable series or rocks. There are sandstones, shales, beds of limestone, and coal; in fact it includes nearly all the different varieties of sediments from coarse sandstone and conglomerate to the finest grained shale. These change rather rapidly from one to the other so that it is often impossible to trace a horizon for any great distance...... Shale is the most abundant rock in the series. The higher shales are often red in the northern part of the area, while to the south red is the prevailing color of the shale throughout the whole series...... Most of the limestones occur in the northern part of the area where the sandstones are but poorly developed. As the limestones are traced southward they pass into calcareous shales which are often full of nuggets of lime. Finally these disappear, as do also nearly all traces of the coal beds, and the series becomes one of chiefly shale and sandstone. These latter increase materially in importance in the southern part of the Dunkard field."

Following the classification of Stevenson, the Permian beds of Ohio are subdivided into the Washington below and the Greene above.

Washington Series

The lower part of the Permian beds in Ohio extending from the top of the Waynesburg coal to the top of the Upper Washington limestone comprise the Washington series. [3] The total average thickness of this series in Ohio is about 220 feet. Four distinct coal beds and five limestone horizons are present, the rest of the group consisting of sandstone and shale. The limestones, which are of the fresh water type, consist in ascending order of the Elm Grove, Mount Morris, Lower Washington, Middle Washington, and Upper Washington. They are widely distributed through the series but those having the most importance are confined stratigraphically to the upper part and geographically to the northern part of the belt of outcrops. The limestone members will be described briefly in ascending order.

Elm Grove Limestone

The Elm Grove limestone, first named by Grimsley for exposures near Elm Grove, Ohio County, West Virginia, [4] is a thin limestone lying near the base of the series and a few feet above the Waynesburg coal from which it is generally separated by shale. In Ohio the horizon of this limestone outcrops over a narrow belt extending from southern Jefferson County to eastern Meigs County but the thickest and most continuous deposits are confined to Belmont County. Local wants of the member are generally due to encroachment by the overlying Waynesburg sandstone. The Elm Grove is generally a dark blue to almost black limestone

[1] *Fontaine, Wm. M., and White, I. C., The Permian or upper Carboniferous flora of West Virginia and southwest Pennsylvania: Second Geol. Survey Pa. Rep't. PP, pp. 24-25, 105-120.*

[2] *Stauffer, C. R. and Schroyer, C. R., The Dunkard series of Ohio: Geol. Survey Ohio Bull. 22, p. 15, 1920.*

[3] *Stevenson, J. J., op. cit., pp. 34-35, 1876*

[4] *Grimsley, G. P., Rep't. Ohio, Brooke, and Hancock counties: W. Va. Geol. Survey, pp. 68-69, 1906.*

which on weathering develops a peculiar slaty structure. Where present the thickness of the member varies from a few inches to about 5 feet but will not average more than 2 feet. The importance of the Elm Grove as a local source of limestone is slight.

Mount Morris Limestone

The stratigraphic position of the Mount Morris limestone is close below the Waynesburg A coal. It was first named by White for its occurrence near Mount Morris, Greene County, Pennsylvania,[1] where it is a well developed member of the Washington series. In eastern Ohio, however, the Mount Morris is very local in its occurrence. Outcrops have been recognized at a few localities in southern Jefferson County and in Belmont County where the member consists of nodules or thin layers of limestone of the fresh or brackish water type embedded in argillaceous shales and occurring some 30 to 40 feet above the horizon of the Waynesburg coal. No economic importance can be attached to this member as a source for limestone.

Lower Washington Limestone

The Lower Washington limestone was first named by Stevenson for exposures near Washington, Washington County, Pennsylvania[2] where it is found immediately overlying the Washington coal. In Ohio the known distribution of this limestone member on the outcrop is confined chiefly to Belmont County. Here it tends to be patchy and discontinuous. It is generally a gray to light buff limestone often nodular in character but occasionally occurring in compact well defined layers interstratified with shale. The Lower Washington varies in thickness from a few feet to nearly 20 feet. It is generally separated from the Washington coal by a thin bed of arenaceous shale or shale and thin sandstone.

Middle Washington Limestone

Like the Lower Washington limestone the Middle Washington limestone, first named and described by Stevenson,[3] is confined in its known distribution on the outcrop in Ohio chiefly to Belmont County. Here it varies in thickness from 5 to 20 feet and tends to be more persistent than the Lower Washington limestone previously described. It consists for the most part of gray to bluish gray stone in nodular or lens-like form embedded in calcareous shale. The stratigraphic position of this limestone member is on an average about 27 feet above the top of the Lower Washington limestone and about 54 feet above the top of the persistent Washington coal.

Upper Washington Limestone

The top member of the Washington series in Washington County, Pennsylvania, is a well defined limestone measuring 30 feet in thickness at Washington, which Stevenson named the Upper Washington limestone.[4] In Ohio this limestone is relatively unimportant as the member has been recognized only over small areas in Belmont County and in northern Monroe County. Elsewhere its horizon is occupied by sandstones and shales. The limestone is of the fresh or brackish water type and consists of nodules or lens-like layers of gray, blue, or buff limestones inter-

[1] *White, I. C., Stratigraphy of the bituminois coal fields of Pennsylvania, Ohio and West Virginia: U. S. Geol. Survey Bull. 65, pp. 39-40, 1891.*

[2] *Stevenson, J. J., Greene and Washington districts: Second Geol. Survey Pa. Rep't. K, pp. 44, 50, 1876.*

[3] *Stevenson, J. J., op. cit., pp. 44, 48-50, 1876.*

[4] *Stevenson, J. J., op. cit., pp. 45-47, 1876.*

bedded with shales. The thickness of the member ranges from a few inches to 23 feet but an average of 12 measurements is about 7 feet. It is closely overlain by the Jollytown "A" coal, the basal member of the Greene series. Its position in Belmont County is on an average about 100 feet above the Washington coal.

Greene Series

In Greene County, Pennsylvania, the Upper Washington limestone is overlain by a series of strata having a maximum thickness of about 800 feet which was first described by Stevenson and named by him the Greene County Group.[1] The lower part of this group is represented in Ohio by a series of variable character forming the higher hills and ridges in southern Belmont County, in eastern Monroe County, and in parts of Washington County. The total maximum thickness of this series in Ohio is about 370 feet. Occasional outcrops show the series to be composed in large part of shale with minor amounts of sandstone. Two or more thin impure coal beds have been recognized and a zone of more or less nodular limestone is occasionally present in the upper part of the series exposed. The areal extent of the limestone is small and its economic importance is trivial.

[1] *Stevenson, J. J., op. cit., pp. 35-37, 1876.*

CHAPTER III

DISCUSSION BY COUNTIES

ASHLAND COUNTY

General Considerations

Ashland County, which includes an area of about 426 square miles, is located along the northwestern edge of the Allegheny Plateau almost entirely within the glaciated part. The region is drift covered except a small area in Hanover Township in the southern end. The bedrocks which are exposed at the surface or immediately underlie the glacial drift consist of sandstone and shale belonging to the Cuyahoga and Logan formations of the Mississippian system and to the Pottsville series of the Pennsylvanian system. No limestone formations occur in surface outcrops. The Maxville limestone which in normal succession overlies the Logan formation and underlies the Pottsville series was entirely worn away by pre-Pennsylvanian erosion. Records of wells drilled for oil and gas indicate that in the subsurface series the Middle Devonian limestones are first encountered at depths below sea level ranging from zero feet in the northwest corner to about 550 feet in the southeast part of the county.

ASHTABULA COUNTY

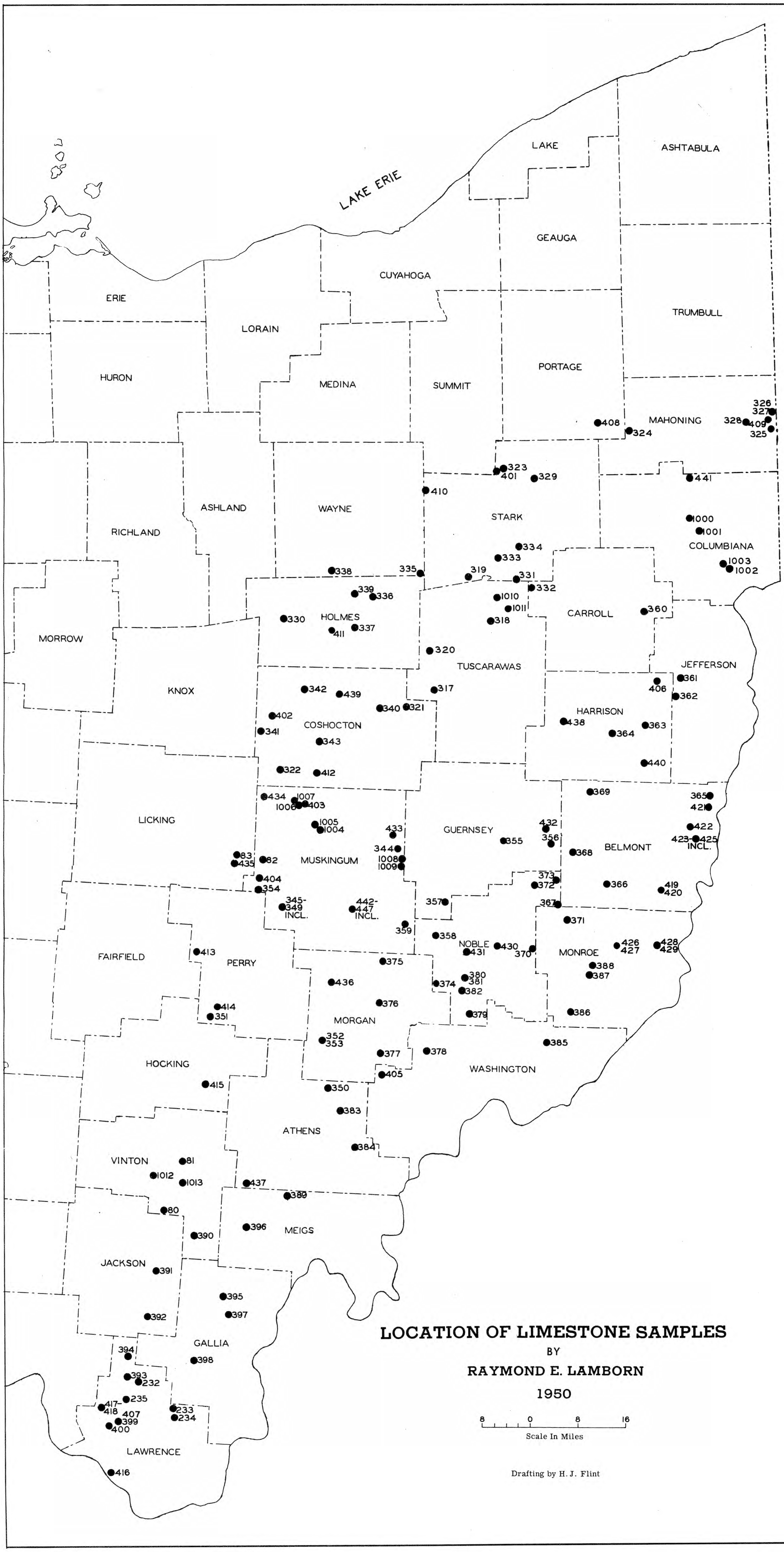
General Considerations

The bedrocks which reach the surface or immediately underlie the glacial drift in the 710-mile area comprising Ashtabula County consist entirely of sandstone and shale. The rock series represented includes the Cleveland and Chagrin shales of Upper Devonian age, and the Bedford, Berea, Sunbury, and Cuyahoga formations of Mississippian age. Outcrops of the Devonian shales are widespread in the central and northern parts of the county, but are confined to the large valleys in the southern part. They are overlain by Mississippian beds west of the Grand River in the southwestern part and on both sides of Pymatuming Creek in the southeastern part. Well records indicate that the Upper Devonian shales in this county exceed 1,800 feet in thickness and that the underlying Middle Devonian limestone is reached at depths below sea level ranging from 700 feet in the northwestern part to 1,700 feet in the southeastern part of the county.

ATHENS COUNTY

General Considerations

The series of bedrocks which reach the surface in Athens County include strata varying in age from basal Allegheny to middle Permian. Owing to the general eastern inclination of the beds, the oldest series exposed, the Allegheny, is confined in its distribution at the surface to the northwestern part of the county. Outcrops of this series occur over elongated belts along the valleys of Hewitt Fork in Waterloo and York townships, the Hocking River in York and Dover townships, and Sunday Creek and its tributaries in Trimble and Dover townships. Overlying the Allegheny in ascending order are the Conemaugh and Monongahela groups of the Pennsylvanian. These series are exposed over broad belts extending in a north-south direction across the county and compose most of the rock outcrops in the western two-thirds of the area. Beds of Permian age are confined in their distri-



LOCATION OF LIMESTONE SAMPLES
BY
RAYMOND E. LAMBORN
1950

LIST OF SAMPLES

NO.	FORMATION OR MEMBER
80	VANPORT
81	ZALESKI
82	UPPER MERCER
83	VANPORT
232	CAMBRIDGE
233	BRUSH CREEK
234	CAMBRIDGE
235	BRUSH CREEK
317	VANPORT
318	VANPORT
319	PUTNAM HILL
320	VANPORT
321	LOWER MERCER
322	PUTNAM HILL
323	PUTNAM HILL
324	LOWER MERCER
325	VANPORT
326	VANPORT
327	VANPORT
328	LOWER MERCER
329	PUTNAM HILL
330	PUTNAM HILL
331	PUTNAM HILL
332	PUTNAM HILL
333	PUTNAM HILL
334	PUTNAM HILL
335	PUTNAM HILL
336	PUTNAM HILL
337	PUTNAM HILL
338	PUTNAM HILL
339	PUTNAM HILL
340	LOWER MERCER
341	PUTNAM HILL
342	PUTNAM HILL
343	LOWER MERCER
344	CAMBRIDGE
345	MAXVILLE
346	MAXVILLE
347	MAXVILLE
348	MAXVILLE
349	MAXVILLE
350	AMES
351	MAXVILLE
352	FISHPOT
353	FISHPOT
354	MAXVILLE
355	SUMMERFIELD
356	SUMMERFIELD
357	AMES
358	FISHPOT
359	FISHPOT
360	AMES
361	AMES
362	AMES
363	REDSTONE
364	REDSTONE
365	WASHINGTON
366	FISHPOT
367	FISHPOT
368	FISHPOT
369	PITTSBURGH
370	FISHPOT
371	FISHPOT
372	SUMMERFIELD
373	FISHPOT
374	BENWOOD-UNIONTOWN
375	FISHPOT
376	FISHPOT
377	BENWOOD-UNIONTOWN
378	BENWOOD-UNIONTOWN
379	BENWOOD
380	FISHPOT
381	FISHPOT
382	BENWOOD-UNIONTOWN
383	FISHPOT
384	FISHPOT
385	REDSTONE
386	BENWOOD
387	REDSTONE
388	FISHPOT
389	PITTSBURGH
390	VANPORT
391	VANPORT
392	VANPORT
393	VANPORT
394	VANPORT
395	CAMBRIDGE
396	CAMBRIDGE
397	BRUSH CREEK
398	CAMBRIDGE
399	VANPORT
400	VANPORT
401	LOWER MERCER
402	PUTNAM HILL
403	PUTNAM HILL
404	VANPORT
405	BENWOOD
406	PITTSBURGH
407	FERRIFEROUS
408	LOWER MERCER
409	LOWELLVILLE
410	LOWER MERCER
411	PUTNAM HILL
412	LOWER MERCER
413	MAXVILLE
414	UPPER MERCER
415	LOWER MERCER
416	MAXVILLE
417	VANPORT
418	VANPORT
419	FISHPOT
420	FISHPOT
421	BENWOOD
422	ELM GROVE
423	FISHPOT
424	FISHPOT
425	FISHPOT
426	BENWOOD
427	BENWOOD
428	BENWOOD
429	ARNOLDSBURG
430	SUMMERFIELD
431	EWING
432	SUMMERFIELD
433	BLOOMFIELD
434	LOWER MERCER
435	LOWER MERCER
436	AMES
437	BRUSH CREEK
438	AMES
439	LOWER MERCER
440	FISHPOT
441	SALEM
442	MAXVILLE
443	MAXVILLE
444	MAXVILLE
445	MAXVILLE
446	MAXVILLE
447	MAXVILLE
1000	LOWER FREEPORT
1001	UPPER FREEPORT
1002	CAMBRIDGE
1003	AMES
1004	LOWER MERCER
1005	PUTNAM HILL
1006	VANPORT
1007	HAMDEN
1008	CAMBRIDGE
1009	AMES
1010	UPPER MERCER
1011	PUTNAM HILL
1012	VANPORT
1013	VANPORT

bution for the most part to the higher slopes and ridge tops in Troy, Carthage, Rome, and Bern townships in the eastern part. The total vertical thickness of the series outcropping in Athens County is not far from 1,075 feet. The details of the rock succession deduced in part by the writer from unpublished field notes and sections of Wilber Stout and assistants are as follows:[1]

Generalized Section of Bedrocks Outcropping In Athens County

	Ft.	In.
Permian system		
Washington series		
Sandstone and shale with probably one or more thin coals. Series not detailed. Approximate thickness	260	0
Pennsylvanian system		
Monongahela series		
Shale, carbonaceous to coaly, Waynesburg or No. 11	-	1/8
Shale, gray, arenaceous, and shaly sandstone, Gilboy sandstone horizon	14	10
Coal, shaly, Little Waynesburg	-	2
Clay shale, gray	1	4
Limestone, generally gray, local, Waynesburg	-	8
Shale, generally pink, calcareous, with occasional nodules of limestone	20	5
Shale, gray, arenaceous, and shaly sandstone, Uniontown sandstone horizon	16	3
Shale, dark, carbonaceous, and shaly coal, Uniontown or No. 10	-	1
Shale, gray to pink, calcareous, with nodules and thin beds of limestone, Uniontown limestone horizon	20	0
Shale, sandy, and shaly sandstone, Arnoldsburg sandstone horizon	17	0
Coal and black shale rarely present, Arnoldsburg	-	1
Shale, gray to pink, calcareous, with some thin limestone	9	8
Limestone, gray to bluish gray, thin to thick bedded with shale partings, Benwood-Arnoldsburg	23	7
Shale, pinkish, calcareous, with occasional nodules and thin layers of limestone	18	3
Shale, arenaceous, and shaly sandstone, Sewickley sandstone horizon	13	7
Shale, gray, arenaceous	3	3
Coal and black shale, locally present, Meigs Creek or No. 9	1	1
Shale, gray, generally arenaceous with some shaly sandstone, Lower Sewickley or Fishpot sandstone horizon	24	2
Coal and black shale, Fishpot	-	1
Limestone, gray to bluish or brownish gray, in layers separated by calcareous shale partings, Fishpot	20	9
Shale, arenaceous, with local bodies of sandstone, Pomeroy sandstone horizon	19	4
Coal, shaly, Redstone, Pomeroy or No. 8a	1	0

[1] *Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17, pp. 106-107, 1912.*

Shale, gray, generally arenaceous, locally replaced by sandstone, Pittsburgh sandstone horizon	20	7
Coal, with partings, locally present, Pittsburgh or No. 8	2	11
Conemaugh series		
Limestone in layers and nodules interbedded with clay, Pittsburgh	16	0
Sandstone, massive; especially prominent along the Hocking east of Athens, Connellsville	45	0
Shale, carbonaceous, and thin coal, Clarksburg	-	-
Limestone, nodular, Clarksburg	1	6
Clay shale, mostly red, with nodular layers of limestone and hematite common, irregular sandy beds also present	50	0
Sandstone, conglomeratic at base, Morgantown	25	0
Clay, with fossiliferous limestone nodules, Skelley horizon	2	0
Clay shale, red	22	0
Limestone, gray, fossiliferous, Ames	2	0
Clay, red	29	0
Sandstone, shaly	26	0
Limestone, fossiliferous, nodular; underlain by black shale with many fossils, Portersville	3	0
Coal, thin, Anderson	-	-
Clay, reddish brown	12	0
Sandstone, calcareous, with marine fossils; impure limestone in some localities, Cambridge horizon	2	0
Shale, sandy	26	0
Limestone, fossiliferous (Brush Creek)	1	0
Shale, sandy (Brush Creek)	12	0
Limestone, rusty gray, mottled, fossiliferous (Brush Creek)	1	0
Shale, carbonaceous	3	0
Coal, thin, Mason	-	-
Shale, sandy	33	0
Coal streak, Mahoning	-	-
Clay	3	0
Sandstone, massive to shaly, Mahoning	36	0
Allegheny series		
Shale, sandstone, coal, clay, and limestone. The Lower and Upper Freeport limestones occur in this series. Approximate thickness exposed	200	0

The limestone beds outcropping in Athens County which occur locally in sufficient thickness for quarrying and which possess qualities necessary for utilization are confined chiefly to the Conemaugh and Monongahela groups. The most important of these members are the Brush Creek, Ames, Pittsburgh, Fishpot, and the Benwood-Arnoldsburg. Quarries have operated at various times in Lee, Rome, Bern, and Carthage townships to supply local needs chief of which is stone for road purposes and for agricultural lime.

Nothing is known concerning the presence below drainage of the thin limestones of the Pottsville and lower Allegheny series. Records of wells drilled for oil and gas reveal the presence within this county of scattered remnants of Maxville limestone. The largest known deposit of this formation occurs in north central and northeastern Lodi Township and southeastern Canaan Township. Here the Maxville, ranging in thickness from 5 to 60 feet, is found at depths from the surface varying from 950 to 1,150 feet. Records of a number of wells drilled near Canaanville in Section 15, Canaan Township, show variations in thickness for this limestone of 40 to 60 feet. Smaller remnants ranging from 20 to 30 feet thick have been penetrated in sections 20 and 28, Ames Township. Likewise in sections 32 and 33, Carthage Township, this formation is represented by deposits 15 to 50 feet in thickness. In Sections 19 and 25, Waterloo Township, and in Section 24, Lee Township, bodies of Maxville varying from 20 to 70 feet in thickness have been reached in wells at depths of 440 to 600 feet.

Lower and Upper Freeport Limestones

Outcrops of the Lower and Upper Freeport limestone horizons, which occur close below the Lower and Upper Freeport coals respectively, are confined to the valleys of Hewitt Fork, Hocking River, and Sunday Creek in the northwestern and western parts of Athens County. No unusual development of these members which are normally thin, patchy in distribution, and nodular in character, are known to occur in this area.

Brush Creek Member

From Columbia Township, Meigs County, the belt of outcrops of the Brush Creek extends to the north across the western part of Athens County, including parts of Lee, Alexander, Waterloo, Athens, York, Dover, and Trimble townships. The member consists of two limestones which "are ordinarily in two layers, each about one foot thick, separated by 12 to 20 feet of sandy shale. The rock is dark gray and spotted rusty brown on the surface, but the interior shows greenish and reddish mottled tints."[1] The upper part often shows the thicker development, but both beds tend to be siliceous and impure. The stone has been quarried near Albany in the southeastern part of Lee Township and marketed for road stone.

James Dixon has operated a quarry in the Brush Creek limestone on the Fred Johnston property in the northeast quarter of Section 13, Lee Township. The quarry is located near the crest of the high ground north of U. S. Route 50 and about one-eighth of a mile east of Flat Run. A section of the beds exposed is as follows:

		Ft.	In.
Shale, arenaceous		5	0
Limestone, gray, hard, flinty	Brush Creek	-	8
Shale, calcareous	Brush Creek	-	9
Limestone, bluish, hard, flinty	Brush Creek	1	0
Shale, light bluish gray, sandy	Brush Creek	-	4
Limestone, gray to bluish gray, flinty	Brush Creek	4	0
Bottom of quarry.			

The three limestone beds described above, having a total combined thickness of 5 feet 8 inches, were sample for chemical analysis on July 13, 1944, by R. E. Lamborn.

[1] *Condit, D. D., op. cit., p. 109.*

Sample No. 437

Chemical analysis of Brush Creek limestone from quarry on Fred Johnston property, Section 13, Lee Township, Athens County, E. Chadbourn, analyst.

	Per cent
Silica, SiO_2	38.38
Alumina, Al_2O_3	2.19
Ferric oxide, Fe_2O_3	0.19
Ferrous oxide, FeO	0.71
Iron disulphide, FeS_2	0.04
Magnesium oxide, MgO	0.49
Calcium oxide, CaO	31.10
Sodium oxide, Na_2O	0.37
Potassium oxide, K_2O	0.18
Water, hydroscopic, H_2O-	0.31
Water, combined, H_2O+	0.86
Carbon dioxide, CO_2	24.68
Titanium dioxide, TiO_2	0.13
Phosphorus pentoxide, P_2O_5	0.16
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.17
Total	100.00

The per cent of each of the mineral components in Sample No. 437 as determined by calculation (Lamborn) from the chemical analysis is listed below.

Silica and hydrated aluminum silicates of solium and potassium	41.95
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.22
Ferrous carbonate, $FeO.CO_2$	1.14
Iron disulphide, FeS_2	0.04
Titanium dioxide, TiO_2	0.13
Calcium phosphate, $3CaO.P_2O_5$	0.35
Calcium sulphate, $CaO.SO_3$	0.07
Calcium carbonate, $CaO.CO_2$	55.12
Magnesium carbonate, $MgO.CO_2$	1.02
Manganese carbonate, $MnO.CO_2$	0.28
Water, hydroscopic, H_2O-	0.31
Unbalanced components (excess CO_2 used)	-0.63
Total	100.00

Cambridge Limestone

The Cambridge limestone which occurs from 20 to 25 feet above the Brush Creek and about 115 feet above the Upper Freeport coal is not strongly expressed on the outcrop in this county. According to Condit[1] it is invariably thin; in some places is replaced by sandy shales, and at others localities it is represented by a thin layer of calcareous sandstone. Its economic importance for its lime content is negligible in this area.

Portersville Member

This member is represented on the outcrop by a few inches of nodular limestone underlain by black shale possessing no importance except for its stratigraphic and paleontologic interest.

[1] *Op. cit., pp. 104-121.*

Ames Limestone

The Ames limestone was first named by E. B. Andrews in 1873 for its occurrence near Amesville, Ames Township, Athens County,[1] where it is a well developed and persistent limestone member of the Conemaugh. From the western part of this township the outcrops extend to the west and northwest through eastern Trimble and eastern Dover townships and to the south and southwest through western Canaan, Athens, eastern Waterloo, and Alexander townships. Its position in the rock series can be well defined as it is usually found in this county about 160 feet below the Pittsburgh coal. It is generally a gray to greenish gray limestone of good purity, but in places assumes a rusty brown appearance on weathering. Its field of thickest and best known development in this county occurs in Ames Township. The limestone has been quarried near Amesville and utilized for the production of agricultural lime.

The Ames limestone with its overlying and underlying shales is well exposed on the north side of the road in the northwest quarter of Section 11, Ames Township, about one-fourth mile southeast of the church. Wilber Stout describes the exposures at this locality as follows:

	Ft.	In.
Shale, pink	7	0
Limestone, hard, bluish gray, fossiliferous, Ames	1	7
Shale, pinkish, siliceous	10	0

The Ames limestone at this locality was sampled by Wilber Stout on June 25, 1941, for chemical analysis

Sample No. 350

Chemical analysis of Ames limestone from outcrop along public road, Section 11, Ames Township, Athens County, Downs Schaaf, analyst.

	Per cent
Silica, SiO_2	3.11
Alumina, Al_2O_3	0.27
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	0.47
Iron disulphide, FeS_2	0.03
Magnesium oxide, MgO	0.40
Calcium oxide, CaO	52.40
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	0.01
Water, hydroscopic, H_2O-	0.18
Water, combined, H_2O+	0.06
Carbon dioxide, CO_2	42.08
Titanium dioxide, TiO_2	0.04
Phosphorus pentoxide, P_2O_5	0.21
Sulphur trioxide, SO_3	0.07
Manganous oxide, MnO	0.77
Carbon, organic, C	0.02
Hydrogen, organic, H	----
Total	100.15

[1] *Andrews, E. B., Report on Athens County: Geol. Survey Ohio Vol. 1, Pt. I, p. 271, 1873.*

The per cent of each of the various compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.08
$Al_2O_3.2SiO_2.2H_2O$	0.60
Silica, SiO_2	2.79
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.03
Ferrous carbonate, $FeO.CO_2$	0.76
Iron disulphide, FeS_2	0.03
Titanium dioxide, TiO_2	0.04
Calcium phosphate, $3CaO.P_2O_5$	0.46
Calcium sulphate, $CaO.SO_3$	0.12
Calcium carbonate, $CaO.CO_2$	92.99
Magnesium carbonate, $MgO.CO_2$	0.84
Manganese carbonate, $MnO.CO_2$	1.25
Water, hydroscopic, H_2O-	0.18
Organic matter	0.02
Unbalanced components (excess CO_2, H_2O)	-0.04
Total	100.15

Skelley Limestone

The Skelley limestone consists in this county of small nodular fossiliferous limestone embedded in clay. Its importance here is limited entirely to its stratigraphic interest.

Pittsburgh Limestone

The Pittsburgh limestone has been recognized on the outcrop in Alexander, Lodi, Athens, Canaan, Rome, Dover, Ames, and Bern townships. It is by no means persistent or constant for at many localities its horizon is occupied by sandy shales. Where present the limestone member varies from 1 to 15 feet in thickness. It is probably best developed in Lodi Township where it consists of several layers of somewhat impure limestone interstratified with calcareous shales, the series having a total thickness of approximately 10 feet. Owing to the presence of thicker and more heavily-bedded limestones in the overlying Monongahela, the Pittsburgh has not been utilized to any extent in this county.

Redstone Limestone

The Redstone limestone which occurs close below the Redstone coal and which is well developed in eastern Ohio is scarcely worthy of mention in Athens County where its horizon is occupied chiefly with arenaceous shale and sandstone with only local deposits of thin limestone.

Fishpot Limestone

In Athens County the field of outcrops of the Fishpot limestone includes parts of Alexander, Lodi, eastern Athens, Canaan, Rome, eastern Dover, Ames, and Bern townships. The member consists of more or less well defined layers of gray to bluish gray limestone interstratified with beds of calcareous shale which vary from a few inches to several feet in thickness. The thickness of the member ranges from 1 or 2 feet to as much as 20 to 30 feet. The limestone layers tend to be more regular and heavy bedded, and to occur with thinner shale partings in the top part of this member which is found only a few feet below the Fishpot coal. This heavy bedded portion has been the source for most of the limestone secured locally for road construction in the eastern part of the county. Quarries have operated in the Fishpot limestone in Bern and in Rome townships.

The Fishpot limestone was formerly quarried at two localities on opposite sides of the public road in the southwest part of Section 32, Bern Township. Crushed limestone for road construction was the chief product of these quarries, although small quantities of pulverized stone were marketed for agricultural lime. The exposures in the quarry on the west side of the road, located on the Gilbert Baudinot property, are described as follows:

		Ft.	In.
Shale, sandy, and shaly sandstone, estimated thickness		10	0
Shale, black, carbonaceous, Fishpot coal horizon		-	2
Shale, bluish gray to greenish gray, with scattered nodules of limestone, not sampled		4	8
Limestone, bluish gray to light chocolate brown, sampled	Fishpot	1	6
Limestone, bluish gray to light chocolate brown, sampled	Fishpot	-	10
Shale, calcareous, with limestone nodules, not sampled	Fishpot	-	2 1/2
Limestone, bluish gray, dense, somewhat brittle, sampled	Fishpot	1	3
Shale, calcareous, not sampled	Fishpot	-	1
Limestone, bluish gray to light chocolate brown, sampled	Fishpot	1	0
Shale, hard, calcareous, not sampled	Fishpot	-	3
Limestone, bluish gray to light chocolate brown, dense, sampled	Fishpot	1	0
Shale, not sampled	Fishpot	-	1
Limestone, bluish gray, dense, sampled	Fishpot	-	6
Bottom of quarry.			

The limestone beds exposed in this quarry, having a total combined thickness of 6 feet 1 inch, were sampled by R. E. Lamborn on June 23, 1942, for chemical analysis.

Sample No. 383

Chemical analysis of Fishpot limestone from quarry on Gilbert Baudinot property, Section 32, Bern Township, Athens County, Nalin Laboratories, analysts.

	Per cent
Silica, SiO_2	7.02
Alumina, Al_2O_3	1.76
Ferric oxide, Fe_2O_3	0.53
Ferrous oxide, FeO	0.67
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	1.46
Calcium oxide, CaO	47.55
Strontium oxide, SrO	<0.01
Barium oxide, BaO	0.20
Sodium oxide, Na_2O	0.16
Potassium oxide, K_2O	0.11
Water, hydroscopic, H_2O-	0.12
Water, combined, H_2O+	0.35
Carbon dioxide, CO_2	38.88
Titanic oxide, TiO_2	0.06
Phosphorus pentoxide, P_2O_5	0.32
Sulphur trioxide, SO_3	0.12
Manganous oxide, MnO	0.03
Carbon, organic, C	0.67
Hydrogen, organic, H	0.08
Total	100.09

The per cent of each of the various mineral compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	2.90
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.55
Silica, SiO_2	4.95
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.62
Ferrous carbonate, $FeO.CO_2$	1.08
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.06
Calcium phosphate, $3CaO.P_2O_5$	0.70
Calcium sulphate, $CaO.SO_3$	0.03
Barium sulphate, $BaO.SO_3$	0.30
Calcium carbonate, $CaO.CO_2$	84.17
Magnesium carbonate, $MgO.CO_2$	3.05
Manganese carbonate, $MnO.CO_2$	0.05
Water, hydroscopic, H_2O-	0.12
Organic matter	0.75
Unbalanced components (excess CO_2, H_2O)	-0.24
Total	100.09

The State Highway Department has operated a quarry in the Fishpot limestone on the east bank of the Hocking River in the northeast quarter of Section 20, Rome Township. The quarry is located about one-eighth of a mile south of the railroad bridge and about five-eighths of a mile southwest of Stewart. The rock exposures here are described as follows:

	Ft.	In.
Soil and weathered shale	5	0

			Ft.	In.
Limestone, light bluish to chocolate brown, sampled	Fishpot		1	0
Shale, calcareous, not sampled			-	1
Limestone, light chocolate brown and bluish gray mottled, sampled			-	9
Shale, calcareous, not sampled			-	1
Limestone, light bluish gray to light chocolate brown, dense, sampled			1	1
Shale, calcareous, not sampled			-	1/2
Limestone, bluish gray to light chocolate brown, dense, sampled			-	6
Shale, calcareous, not sampled			-	1/2
Limestone, bluish gray, dense, sampled			-	11
Shale, bluish gray, calcareous, not sampled			-	1
Limestone, brownish gray, dense, with minute veins of calcite, sampled			1	0
Bottom of quarry.				

The limestone layers having an aggregate thickness of 5 feet 3 inches were sampled by R. E. Lamborn on June 23, 1942, for chemical analysis.

Sample No. 384

Chemical analysis of Fishpot limestone from quarry of State Highway Department, Section 20, Rome Township, Athens County, Nalin Laboratories, analysts.

	Per cent
Silica, SiO_2	5.73
Alumina, Al_2O_3	1.48
Ferric oxide, Fe_2O_3	0.80
Ferrous oxide, FeO	0.59
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.93
Calcium oxide, CaO	49.09
Strontium oxide, SrO	<0.01
Barium oxide, BaO	0.08
Sodium oxide, Na_2O	0.19
Potassium oxide, K_2O	0.22
Water, hydroscopic, H_2O-	0.10
Water, combined, H_2O+	0.23
Carbon dioxide, CO_2	39.81
Titanic oxide, TiO_2	0.10
Phosphorus pentoxide, P_2O_5	0.04
Sulphur trioxide, SO_3	0.16

Manganous oxide, MnO	0.03
Carbon, organic, C	0.55
Hydrogen, organic, H	0.05
Total	100.18

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silica and hydrated aluminum silicates	7.72
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.94
Ferrous carbonate, $FeO.CO_2$	0.95
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.10
Calcium phosphate, $3CaO.P_2O_5$	0.09
Calcium sulphate, $CaO.SO_3$	0.20
Barium sulphate, $BaO.SO_3$	0.12
Calcium carbonate, $CaO.CO_2$	87.38
Magnesium carbonate, $MgO.CO_2$	1.94
Manganese, carbonate, $MnO.CO_2$	0.05
Water, hydroscopic, H_2O-	0.10
Organic matter	0.60
Unbalanced components (excess CO_2)	-0.01
Total	100.18

Benwood-Arnoldsburg Limestone

The Benwood and Arnoldsburg limestone members, which can not be separated in Athens County owing to the absence of the Fulton Green shale, are generally present where due on the outcrop in Bern, Rome, Canaan, Lodi, and Carthage townships. The two members form a continuous series composed of limestone and interbedded shale. The Arnoldsburg is overlain and the Benwood is underlain by thick beds of pink calcareous shale. The thickness of this limestone series varies from 5 to 40 feet. It is best developed on the outcrop in Bern Township in the northeastern part of the county.

For analysis of these limestones see section of this report dealing with the limestone resources in Morgan County.

Uniontown Limestone

The Uniontown limestone, which in normal sequence is found close below the Uniontown coal, is poorly developed in Athens County. Across the eastern part of the area, including Bern, Rome, Canaan, Lodi, and Carthage townships, the horizon of the Uniontown coal is closely underlain by beds of gray to pink calcareous shale ranging from 10 to 40 feet in thickness. Scattered deposits of thin limestone representing the Uniontown occur embedded in the upper part of these shales, but their economic importance is trifling.

Waynesburg Limestone

The Waynesburg member in Athens County is represented by thin limestone a foot or less in thickness occurring from 1 to 2 feet below the Little Waynesburg coal. Known deposits of this limestone are confined chiefly to Bern and Rome townships. No economic importance can be attached to this member in Athens County.

BELMONT COUNTY

General Considerations

Belmont County, embracing an area of about 541 square miles, contains within its borders outcrops of bedrock ranging in age from middle Conemaugh to upper Permian. Owing to the regional inclination of the strata in a southeastern direction, exposures of Conemaugh beds are confined to the valley of Stillwater Creek and its tributaries in the northwestern part of the county, to the deep valley of Wheeling Creek, to McMahon Creek Valley below Glencoe, and to the Ohio River Valley as far south as Bellaire. The Conemaugh is overlain by the Monongahela, above which are strata of Permian age. The distribution of the Monongahela outcrops includes elongated areas along all the deep valleys in the eastern and southern parts and an irregular belt across the northwestern part of the county, including much of western Wheeling, eastern Flushing, western Union, and southern Kirkwood townships. The uplands in the southeastern two-thirds of area are found on beds of Permian age. The total thickness of the series outcropping in Belmont County is approximately 1,080.

A generalized section describing the succession, character, and thickness of the numerous beds of limestone, coal, clay, shale, and sandstone comprising the Conemaugh, Monongahela, and Permian groups outcropping in Belmont County is given as follows:[1]

Generalized Section Of Bedrocks Outcropping In

Belmont County

	Ft.	In.
Permian system		
Green series		
Sandstone and shale with an occasional local deposit of nodular limestone and with several thin coal beds. Members not differentiated in this county	280	0
Washington series		
Shale, local in occurrence	2	0
Limestone, in layers and nodules interstratified with shale, Upper Washington	7	4
Shale, arenaceous	8	5
Sandstone, local, Upper Marietta	6	7
Shale, arenaceous	21	0
Coal, generally wanting, Washington A	--	8
Shale	1	6
Limestone, interstratified with calcareous shale, Middle Washington	9	0
Shale, gray, generally calcareous	27	0
Limestone in layers and nodules embedded in shale, unsteady, Lower Washington	10	4
Shale, gray, arenaceous, with some thin sandstone, Lower Marietta sandstone horizon	16	8
Coal and black shale, persistent, Washington coal horizon	3	3
Shale, gray to bluish, argillaceous	12	7

[1] *Stout, Wilber, The Monongahela series in eastern Ohio: W. Va. Acad. Sci. Proc. Vol. 3, pp. 121-122, 1929.*

Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17, pp. 181-185, 1912;

Stauffer, C. R. and Schroyer, C. R., The Dunkard series of Ohio: Geol. Survey Ohio Bull. 22, 1920.

Coal and carbonaceous shale, local, Little Washington	2	4
Shales, gray, bluish gray to red, variable, with thin beds of gray sandstone Mannington sandstone horizon	43	3
Coal and black shale, Waynesburg A	1	8
Limestone, gray, nodular, and in thin layers, local, Mount Morris	8	0
Shale, gray, arenaceous, with occasional thin sandstone beds, Waynesburg sandstone horizon	40	3
Limestone, dark blue, Elm Grove	3	4
Shale, blue to gray, often fossiliferous, Cassville	6	4
Pennsylvanian system		
Monongahela series		
Coal, Waynesburg	3	2
Shale, siliceous, with shaly sandstones	16	4
Coal, Little Waynesburg	--	4
Limestones with calcareous shale, Waynesburg	10	0
Shales with local lenses of sandstone, Uniontown sandstone horizon	18	4
Coal, Uniontown or No. 10	1	6
Shale and sandstone	9	0
Limestones with calcareous shales, Uniontown	41	0
Shale, siliceous, calcareous, greenish, Fulton Green	3	2
Limestone, with calcareous shale, Benwood	52	7
Shale, calcareous	4	0
Coal, Meigs Creek or No. 9	2	8
Shale, argillaceous	3	0
Sandstone, Lower Sewickley	16	10
Shale, gray, siliceous	3	0
Coal, Fishpot	1	6
Limestones with calcareous shales, Fishpot	26	2
Shale, calcareous	8	0
Coal, Redstone	1	0
Limestones with calcareous shale partings, Redstone	17	5
Shale, calcareous	6	0
Coal and partings, Pittsburgh or No. 8	8	0
Conemaugh series		
Clay	4	0
Limestone, gray, Pittsburgh	2	6
Shale, sandy, Bellaire sandstone in the eastern part of the county	20	0
Limestone in layers and nodules embedded in clay	36	0
Shale, sandy	23	0
Limestone, buff, having embedded lumps of white, Summerfield	2	0
Clay, brownish red, with limestone nodules	45	0
Shale, sandy, with carbonaceous streaks	34	0
Limestone, fossiliferous, very impure, Skelley	--	10
Coal, thin, with dark slaty rock, Duquesne	3	0
Shale, sandy	24	0

Limestone, fossiliferous, wanting in places, a fossiliferous conglomerate in others, Ames	2	0
Shale, sandy	14	0
Coal, thin, Harlem	--	--
Shale, sandy	25	0
Coal, thin, Barton	--	--
Clay, with nodular limestone, Ewing limestone horizon	10	0
Shale, sandy, and shaly sandstone	50	0
Limestone, dark, shaly, fossiliferous, Portersville	--	10
Coal, Anderson	1	6
Clay, with pellets of limestone	17	0
Limestone, yellow, nodular, fossiliferous, Cambridge	1	0

Seventeen separate and distinct limestones outcrop in this county but the Pittsburgh, Redstone, Fishpot, Benwood, and Uniontown mᵒmbers lead in economic importance. These six limestones are similar in general lithologic character and are alike in being of fresh or brackish water origin. Each member consists for the most part of layers of limestone ranging from a few inches to 5 feet or so in thickness separated by thin beds of calcareous shales. They are usually gray to bluish gray in color, are dense and compact in character, and generally contain varying amounts of impurities such as silica, iron oxides, and clay matter. Limestones of this character have been quarried at various times in nearly every township in Belmont County and have been utilized for building stone, for agricultural lime, and for road construction and repair. Natural rock cement was formerly manufactured from native limestone at Barnesville and at Bellaire.

The only limestone formation occurring below drainage in Belmont County which is worthy of consideration here as a possible source of stone by shafting is the Maxville. In normal succession this limestone is present immediately below the coal-bearing series. Records of oil and gas well borings reveal the presence of the Maxville at various localities in Belmont County as follows:

Township		Thickness of limestone. Feet	Depth from surface in wells. Feet
Name	Part		
Colerain	Southeast part	50 to 83	1100 to 1350
Goshen	Southwest corner	50 to 64	1000 to 1330
Mead	West part	50 to 95	1220 to 1400
Richland	Southeast part	35 to 70	1050 to 1300
Somerset	Southwest part	50 to 100	950 to 1300
Union	Southwest corner	40 to 50	1000 to 1350
Washington	North central part	50 to 83	1100 to 1350
Wayne	South half	15 to 70	1000 to 1330

Cambridge Limestone

The Cambridge limestone is due close above drainage along Stillwater Creek in northwestern Flushing Township but it is too thin to warrant more than stratigraphic interest.

Portersville Member

The Portersville consisting of thin nodular limestone and dark shale and occurring some 20 feet above the Cambridge has no economic value for its lime content in this county.

Ewing Beds

Economic usefulness of the Ewing beds outcropping some 230 feet below the Pittsburgh coal in Flushing Township is trifling as they consist chiefly of clay shales in which small nodules and thin lentils of limestone occur embedded.

Ames Limestone

The Ames is generally "a gray fossiliferous limestone about 2 feet thick"[1] where it outcrops along the valley of Stillwater Creek in Flushing and northern Kirkwood townships about 190 feet below the Pittsburgh coal. In some places it is wanting and at others its horizon is represented by a thin limestone conglomerate. The Ames has not been utilized to any extent in this area.

Skelley Limestone

The Skelley limestone occurring on an average about 27 feet above the Ames in northwestern Belmont County is too thin and too impure for economic utilization.

Summerfield Limestone

From eastern Guernsey County the outcrop line of the Summerfield limestone extends to the northeast across Kirkwood and Flushing townships, Belmont County, where the horizon is found on an average about 85 feet below the Pittsburgh coal. This limestone tends to be thin in Belmont County. It is described by Condit as a buff limestone having embedded lumps of white limestone and a total average thickness of about 2 feet. For an analysis of the Summerfield limestone see pages of this report dealing with the member in Guernsey County.

Pittsburgh Limestone

The field of outcrops of the Pittsburgh limestone, which stratigraphically occurs close below the Pittsburgh or No. 8 coal, includes much of Flushing and Kirkwood townships, small areas in western Union and northern Warren townships, the valley of Wheeling Creek from northwestern Wheeling Township to its mouth, the valley of McMahon Creek east of Glencoe, and the Ohio River Valley north of Bellaire. Over this field the Pittsburgh limestone is generally present with a thickness ranging from 1 foot to as much as 7 or 8 feet. It is generally a gray to bluish gray, dense-textured, tough limestone which may occur as a single layer, 1 to 2 feet in thickness, or in several layers separated by calcareous shale partings. The Pittsburgh limestone has some quantitative importance in Belmont County but in its area of occurrence there is generally thicker limestones of equal or better quality in the lower part of the overlying Monongahela. The Pittsburgh, therefore, is but little utilized in this area.

The Pittsburgh limestone has been quarried and crushed for road stone on the Jesse Bethel property in the east central part of Section 8, Flushing Township. Here the member occurs as a single bed of limestone, 3 feet 10 inches in thickness, outcropping at an elevation of about 1,085 feet. The stone is dense in texture, compact and tough in character, and on fresh exposure has a dark bluish gray color. It is overlain by soft calcareous shale which is stripped by shovels along the out-

[1] *Condit, D. D., op. cit., p. 183, 1912.*

crop. A sample of the Pittsburgh limestone at this locality was secured by the writer for chemical analysis on August 8, 1941.

Sample No. 369

Chemical analysis of Pittsburgh limestone from a quarry on Jesse Bethel property, Section 8, Flushing Township, Belmont County, Downs Schaaf, analyst.

	Per cent
Silica, SiO_2	5.75
Alumina, Al_2O_3	1.01
Ferric oxide, Fe_2O_3	0.05
Ferrous oxide, FeO	3.40
Iron disulphide, FeS_2	0.14
Magnesium oxide, MgO	7.63
Calcium oxide, CaO	39.42
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.06
Water, hydroscopic, H_2O-	0.07
Water, combined, H_2O+	0.30
Carbon dioxide, CO_2	41.15
Titanium dioxide, TiO_2	0.12
Phosphorus pentoxide, P_2O_5	0.14
Sulphur trioxide, SO_3	0.48
Manganous oxide, MnO	0.38
Carbon, organic, C	0.02
Hydrogen, organic, H	--
Total	100.14

The per cent of each of the various compounds probably present in the sample has been computed (Lamborn) from the chemical analysis with results as follows:

Silicates $(Na, K)_2O.Al_2O_3.6SiO_2.2H_2O$	0.75
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.81
Silica, SiO_2	4.56
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.06
Ferrous carbonate, $FeO.CO_2$	5.48
Iron disulphide, FeS_2	0.14
Titanium dioxide, TiO_2	0.12
Calcium phosphate, $3CaO.P_2O_5$	0.30
Calcium sulphate, $CaO.SO_3$	0.82
Calcium carbonate, $CaO.CO_2$	69.46
Magnesium carbonate, $MgO.CO_2$	15.95
Manganese carbonate, $MnO.CO_2$	0.62
Water, hydroscopic, H_2O-	0.07
Organic matter	0.02
Unbalanced components (excess CO_2, H_2O)	-0.02
Total	100.14

Redstone Limestone

The beds and boulder-like masses of fresh water limestone more or less separated by thin calcareous shales, occurring in the interval between the Pittsburgh and Redstone coals, are included in the Redstone limestone member. In Belmont County this limestone is well represented on the outcrop. In places it fills the entire interval between the coals which averages about 24 feet in this county, but elsewhere the base of the limestone is separated from the Pittsburgh coal by a bed of calcareous shale several feet in thickness. The limestone is generally hard and tough, with a dense texture and a gray to bluish gray color, much resembling in general appearance the Pittsburgh limestone previously described. Impurities in the form of clay, sand, and iron oxides are generally present in varying amounts. Although widely distributed on the outcrop close above the Pittsburgh coal in the northwestern corner and along the valleys of Wheeling Creek, McMahon Creek, and the Ohio River in the northeastern quarter, the Redstone has been little utilized in this county. For analyses see pages of this report describing the Redstone limestone in Harrison County.

Fishpot Limestone

The Fishpot limestone, so named by J. J. Stevenson for exposures along Fishpot Creek, Washington County, Pennsylvania, [1] is the most uniform and regularly bedded of all the limestones outcropping in Belmont County. The position of the limestone is in the interval between the Redstone or No. 8a and the Meigs Creek or No. 9 coals and the top of this limestone is generally found just a few feet below the black shale and shaly coal representing the Fishpot coal horizon. The average thickness of the Fishpot member in this county is not far from 25 feet. The limestone layers range in thickness from a few inches to as much as 4 or 5 feet whereas the shale parting varies from a fraction of an inch to 2 feet. The limestone is generally gray to bluish gray in color and dense in texture. Impurities in the form of fine silica, clay matter, and iron oxides are present in varying amounts. On fracture the stone breaks into angular pieces with smooth surfaces and sharp corners and edges. Owing largely to the comparatively good quality and uniform bedding of the upper part of this stone and to the wide distribution of its outcrops, the Fishpot is the chief limestone worked in this county. Quarries have operated in the Fishpot in York, Washington, Wayne, Warren, and Pultney townships chiefly for road stone and to a small extent for agricultural lime. Formerly the Fishpot limestone was mined near Barnesville and utilized for the production of natural rock cement. [2]

The limestone operations of Campbell & Dew are located about 1 mile northwest of Barnesville in the southeast corner of Section 22, Warren Township. At this place the Fishpot limestone is being mined by underground methods. The member, consisting for the most part of ledges of hard compact stone varying from a few inches to 2 feet 8 inches in thickness separated by thin shale parting, has a height exposed here of about 16 feet. The upper ledge of limestone forms the roof of the mine below which about 14 feet of strata is removed. Crushed limestone for road construction is the chief product of the quarry operations. The following is a description of the rock exposures in the mine and on the hillside above the mouth of the opening:

		Ft.	In.
Shale, gray		5	0
Shale, black, carbonaceous		--	7
Coal, good	Fishpot	1	3
Clay shale	Fishpot	--	2 1/2
Coal and black shale	Fishpot	--	9
Shale, black, carbonaceous	Fishpot	--	8

[1] *Stevenson, J. J., Greene and Washington districts: Pennsylvania 2nd Geol. Survey, Rep't. K, p.67, 1876.*

[2] *Lord, N. W., Natural and artificial cements: Geol. Survey Ohio Vol. VI, pp. 672-673, 1888.*

Limestone, bluish gray, one layer, serves as roof of mine			2	2
Shale, calcareous, not sampled			--	2
Limestone, bluish gray, dense, one layer, sampled			1	0
Shale, calcareous, not sampled			--	2
Limestone, bluish gray, dense, hard, one layer, sampled			--	9
Shale, calcareous, not sampled			--	4
Limestone, bluish gray, dense, one layer, sampled	Fishpot (cont.)		2	2
Shale, dark, calcareous, with limestone nodules, not sampled			--	9
Limestone, bluish gray, dense, one layer, sampled			1	0
Limestone, bluish gray, dense, one layer, sampled			1	9
Shale, calcareous, not sampled			--	1
Limestone, bluish gray, dense, one layer, sampled			2	8
Shale, light green, soft, calcareous, not sampled			2	8
Limestone, bluish gray, dense, hard, one layer, sampled			2	8
Bottom of opening.				

The limestone mined at this locality was sampled by the writer for chemical analysis on August 7, 1941.

Sample No. 368

Chemical analysis of Fishpot limestone from mine of Campbell and Dew, Section 22, Warren Township, Belmont County, Downs Schaaf, analyst.

	Per cent
Silica, SiO_2	12.98
Alumina, Al_2O_3	3.30
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	1.90
Iron disulphide, FeS_2	0.20
Magnesium oxide, MgO	10.65
Calcium oxide, CaO	31.01
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01

Sodium oxide, Na_2O	0.15
Potassium oxide, K_2O	0.60
Water, hydroscopic, H_2O-	0.78
Water, combined, H_2O+	0.95
Carbon dioxide, CO_2	37.00
Titanium dioxide, TiO_2	0.20
Phosphorus pentoxide, P_2O_5	0.12
Sulphur trioxide, SO_3	0.06
Manganous oxide, MnO	0.12
Carbon, organic, C	0.02
Hydrogen, organic, H	--
Total	100.07

The per cent of each of the compounds probably present in Sample No. 368 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	6.92
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.55
Silica, SiO_2	9.09
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	3.06
Iron disulphide, FeS_2	0.20
Titanium dioxide, TiO_2	0.20
Calcium phosphate, $3CaO.P_2O_5$	0.26
Calcium sulphate, $CaO.SO_3$	0.10
Calcium carbonate, $CaO.CO_2$	55.02
Magnesium carbonate, $MgO.CO_2$	22.26
Manganese carbonate, $MnO.CO_2$	0.19
Water, hydroscopic, H_2O-	0.78
Organic matter	0.02
Unbalanced components (deficiency CO_2, H_2O)	+0.38
Total	100.07

The Fishpot limestone occurs near drainage level along the North Fork of Captina Creek in Section 23, Wayne Township. Limestone belonging to this member was formerly quarried below creek level just west of the road in the northwest corner of Section 23 and was utilized for road construction in the township. About one-fourth mile south of this quarry the upper part of the Fishpot member and overlying beds outcrop along the south bank of the North Fork on property belonging to Charles G. Kemp. Here the limestone has been quarried to a limited extent and pulverized for agricultural use. A description of the rock exposures at this locality follows:

		Ft.	In.
Coal, weathered, Meigs Creek or No. 9		3	6
Shale and covered		27	8
Coal and black shale, Fishpot		1	0
Shale, carbonaceous, calcareous		--	5
Limestone, dark bluish gray, dense, flint-like fracture, one layer, sampled	Fishpot	1	2
Limestone, laminated, sampled	Fishpot	--	1
Limestone, light to dark bluish gray, mottled, dense, flint-like fracture, one bed, sampled	Fishpot	2	8

Shale, calcareous, discontinuous, not sampled	Fishpot (cont.)	....	--	6
Limestone, light bluish gray, dense texture, sampled		....	2	6
Bottom of exposure.				

Although only about 7 feet of the upper part of the Fishpot limestone is exposed here, drill records in this vicinity are reported to show 18 feet for the full thickness of the member. A sample of limestone was taken by the writer from the exposures described above on August 7, 1941, and was submitted for chemical analysis.

Sample No. 366

Chemical analysis of Fishpot limestone from outcrops on Chalmer C. Kemp property, Section 23, Wayne Township, Belmont County, Downs Schaaf, analyst.

	Per cent
Silica, SiO_2	7.00
Alumina, Al_2O_3	1.95
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	1.11
Iron disulphide, FeS_2	0.18
Magnesium oxide, MgO	7.41
Calcium oxide, CaO	40.30
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.05
Potassium oxide, K_2O	0.16
Water, hydroscopic, H_2O-	0.53
Water, combined, H_2O+	0.60
Carbon dioxide, CO_2	40.33
Titanium dioxide, TiO_2	0.11
Phosphorus pentoxide, P_2O_5	0.11
Sulphur trioxide, SO_3	0.06
Manganous oxide, MnO	0.17
Carbon, organic, C	0.07
Hydrogen, organic, H	--
Total	100.17

The per cent of each of the components probably present in Sample No. 366 has been computed (Lamborn) from the chemical analysis with results as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.97
Silicates $Al_2O_3.2SiO_2.2H_2O$	3.00
Silica, SiO_2	4.70
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.03
Ferrous carbonate, $FeO.CO_2$	1.79
Iron disulphide, FeS_2	0.18
Titanium dioxide, TiO_2	0.11
Calcium phosphate, $3CaO.P_2O_5$	0.24
Calcium sulphate, $CaO.SO_3$	0.10
Calcium carbonate, $CaO.CO_2$	71.62
Magnesium carbonate, $MgO.CO_2$	15.49
Manganese carbonate, $MnO.CO_2$	0.27
Water, hydroscopic, H_2O-	0.53
Organic matter	0.07

Unbalanced components (deficiency CO_2, H_2O)...........	+0.07
Total	100.17

The Fishpot limestone was formerly worked for road stone in a State quarry located near the Captina Coal Works in the northwest quarter of Section 4, Washington Township. The quarry is located on the east side of Rocky Fork about one-fourth mile above its junction with Captina Creek. The exposures are described as follows:

		Ft.	In.
Shale, black, coaly, Fishpot		1	0
Limestone, not sampled		--	6
Limestone, bluish to brownish gray, sampled	Fishpot	2	6
Shale, calcareous, not sampled	Fishpot	--	5
Limestone, bluish gray, dense, sampled	Fishpot	2	2
Shale, bluish, calcareous, with discontinuous limestone layers, not sampled	Fishpot	1	0
Limestone, bluish to brownish gray, sampled	Fishpot	1	6
Limestone, bluish gray, mottled, sampled	Fishpot	2	6
Shale, calcareous, not sampled	Fishpot	--	5
Limestone, bluish gray, somewhat brittle, sampled. Bottom of Sample No. 420, 9 feet 8 inches of limestone	Fishpot	1	2
Shale, calcareous, not sampled	Fishpot	--	8
Limestone, light brownish gray, brittle, small veins of calcite, sampled	Fishpot	1	5
Limestone, light brownish gray, dense, brittle, with small veins of calcite, sampled. Bottom of Sample No. 419, 2 feet 8 inches of limestone	Fishpot	1	3
Bottom of quarry.			

Two samples of limestone were taken from this quarry on September 14, 1943, and were submitted for analysis. Sample No. 419 is from the 2 feet 8 inches of limestone below the 8-inch shale zone whereas Sample No. 420 represents five overlying layers aggregating 9 feet 10 inches in thickness.

Samples No. 419, 420

Chemical analyses of Fishpot limestone from State Quarry, Section 4, Washington Township, Belmont County, E. Chadbourn, analyst.

	Sample No. 419 Per cent	Sample No. 420 Per cent
Silica, SiO_2	6.23	9.55
Alumina, Al_2O_3	0.84	2.56
Ferric oxide, Fe_2O_3	0.05	0.21
Ferrous oxide, FeO	0.99	1.09
Iron disulphide, FeS_2	0.17	0.45
Magnesium oxide, MgO	4.71	6.86
Calcium oxide, CaO	45.00	38.88
Sodium oxide, Na_2O	0.05	0.13
Potassium oxide, K_2O	0.18	0.56
Water, hydroscopic, H_2O-	0.08	0.26
Water, combined, H_2O+	0.56	0.98
Carbon dioxide, CO_2	40.62	37.82
Titanium dioxide, TiO_2	0.02	0.10
Phosphorus pentoxide, P_2O_5	0.02	0.06
Sulphur trioxide, SO_3	0.02	0.04
Manganous oxide, MnO	0.06	0.07
Total	99.60	99.62

The per cent of each of the mineral components in Sample No. 419 as determined by calculation (Lamborn) from the chemical analysis is given below.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	2.14
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.02
Silica, SiO_2	5.24
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.06
Ferrous carbonate, $FeO.CO_2$	1.60
Iron disulphide, FeS_2	0.17
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO.P_2O_5$	0.04
Calcium sulphate, $CaO.SO_3$	0.03
Calcium carbonate, $CaO.CO_2$	80.25
Magnesium carbonate, $MgO.CO_2$	9.84
Manganese carbonate, $MnO.CO_2$	0.10
Water, hydroscopic, H_2O-	0.08
Unbalanced components (deficiency CO_2, H_2O)	+0.01
Total	99.60

The per cent of each of the mineral components in Sample No. 420 as calculated (Lamborn) from the chemical analysis is given below.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	6.03
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.25
Silica, SiO_2	6.83
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.25
Ferrous carbonate, $FeO.CO_2$	0.76
Iron disulphide, FeS_2	0.45
Titanium dioxide, TiO_2	0.10
Calcium phosphate, $3CaO.P_2O_5$	0.13
Calcium sulphate, $CaO.SO_3$	0.07
Calcium carbonate, $CaO.CO_2$	69.22
Magnesium carbonate, $MgO.CO_2$	14.34
Manganese carbonate, $MnO.CO_2$	0.11
Water, hydroscopic, H_2O-	0.26
Unbalanced components (excess CO_2, H_2O)	-0.18
Total	99.62

The Fishpot limestone is well exposed along the highway overlooking the railroad at the northwest edge of Section 12, Pultney Township. The details of lithology and rock succession at this exposure, where three samples of limestone were secured, are set forth in the following section:

	Ft.	In.
Sandstone, estimated thickness	5	0
Shale, fissile, carbonaceous	1	6
Clay shale	--	2
Coal blossom, Fishpot	1	0
Shale	--	3
Limestone, bluish brown, dense, sampled	--	9 1/2
Shale, not sampled	--	9
Limestone, brown, dense, somewhat laminated, sampled	3	5
Shale, not sampled	--	1
Limestone, brown, sampled	--	8
Shale, not sampled	--	1 1/2
Limestone, gray, dense, sampled. Bottom of Sample No. 425, 5 feet 5 1/2 inches of limestone	--	7
Shale, yellowish brown	--	11
Limestone, grayish brown, dense, somewhat laminated. Limestone is brittle and somewhat argillaceous, Sample No. 423	6	3
Shale, dark bluish brown, not sampled	--	10
Limestone, dark bluish brown, sampled	1	0
Shale, soft bluish gray, not sampled	1	7
Limestone, light to dark brown, hard, tough, sampled	1	10
Shale, calcareous, not sampled	--	1 1/2
Limestone, chocolate brown, shaly, with much carbonaceous material, sampled	--	10
Shale, not sampled	--	1
Limestone, chocolate brown, sampled	--	3
Shale, greenish gray to brownish gray, not sampled	--	10
Limestone, light to dark brown, sampled	1	4
Shale, calcareous, not sampled	--	1
Limestone, light brownish gray, argillaceous, sampled	1	7
Shale, calcareous, not sampled	--	2
Limestone, brown, dense, sampled	--	6
Shale, calcareous, not sampled	--	2
Limestone, brown, dense, sampled	--	8
Shale, bluish gray, not sampled	1	0
Shale, brown, calcareous, not sampled	--	6
Limestone, brown, dense, hard, sampled. Bottom of Sample No. 424, 8 feet 8 inches of limestone	--	8
Shale, calcareous	--	3
Limestone, bouldery, varies from 12 to 20 inches	1	4
Clay shale, bluish gray	4	0
Coal blossom, Redstone or No. 8a	1	6
Shale, dark, carbonaceous	1	6
Shale, bluish gray	1	3
Limestone, bluish gray, impure, irregular beds with shale partings, Redstone	16	10

Clay shale with many limestone boulders.	5	6
Coal blossom, Pittsburgh or No. 8	3	7
Clay	3	0

The Fishpot limestone was sampled in three parts as described in the above section. The samples were cut on September 17, 1943, by R. E. Lamborn.

Samples No. 423, 424, 425

Chemical analyses of three samples of Fishpot limestone from outcrop along highway, Section 12, Pultney Township, Belmont County, E. Chadbourn, analyst.

	Sample No. 423	Sample No. 424	Sample No. 425
	Per cent	Per cent	Per cent
Silica, SiO_2	14.51	10.23	11.15
Alumina, Al_2O_3	3.76	1.67	1.91
Ferric oxide, Fe_2O_3	0.19	0.04	0.25
Ferrous oxide, FeO	1.87	1.58	0.68
Iron disulphide, FeS_2	0.54	0.17	0.26
Magnesium oxide, MgO	12.75	6.81	5.30
Calcium oxide, CaO	27.46	38.96	40.80
Sodium oxide, Na_2O	0.26	0.14	0.08
Potassium oxide, K_2O	0.83	0.26	0.33
Water, hydroscopic, H_2O-	0.49	0.19	0.20
Water, combined, H_2O+	1.30	0.82	0.97
Carbon dioxide, CO_2	35.46	38.44	37.34
Titanium dioxide, TiO_2	0.16	0.07	0.06
Phosphorus pentoxide, P_2O_5	0.08	0.07	0.06
Sulphur trioxide, SO_3	0.08	0.05	0.10
Manganous oxide, MnO.	0.08	0.09	0.07
Total	99.82	99.59	99.56

The mineral components in Sample No. 423 as determined by calculation (Lamborn) from the chemical analysis are stated below.

Silica and hydrated aluminum silicates of of sodium and potassium	20.63
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.22
Ferrous carbonate, $FeO. CO_2$	3.01
Iron disulphide, FeS_2	0.54
Titanium dioxide, TiO_2	0.16
Calcium phosphate, $3CaO. P_2O_5$	0.17
Calcium sulphate, $CaO. SO_3$	0.14
Calcium carbonate, $CaO. CO_2$	48.74
Magnesium carbonate, $MgO. CO_2$	26.65
Manganese carbonate, $MnO. CO_2$	0.13
Water, hydroscopic, H_2O-	0.49
Unbalanced components (excess CO_2)	-1.06
Total	99.82

The mineral components in Sample No. 424 as determined by calculation (Lamborn) from the chemical analysis are as follows:

Silicates $(Na, K)_2O. 3Al_2O_3 . 6SiO_2 . 2H_2O$	3.92
Silicates $Al_2O_3 . 2SiO_2 . 2H_2O$	0.34
Silica, SiO_2	8.26
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.05
Ferrous carbonate, $FeO. CO_2$	2.55

Iron disulphide, FeS_2	0.17
Titanium dioxide, TiO_2	0.07
Calcium phosphate, $3CaO.P_2O_5$	0.15
Calcium sulphate, $CaO.SO_3$	0.09
Calcium carbonate, $CaO.CO_2$	69.33
Magnesium carbonate, $MgO.CO_2$	14.23
Manganese carbonate, $MnO.CO_2$	0.14
Water, hydroscopic, H_2O-	0.19
Unbalanced components (deficiency CO_2, H_2O)	+0.10
Total	99.59

The per cent of each of the mineral components in Sample No. 425 as determined by calculation (Lamborn) from the chemical analysis is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	3.77
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.13
Silica, SiO_2	8.90
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.29
Ferrous carbonate, $FeO.CO_2$	1.10
Iron disulphide, FeS_2	0.26
Titanium dioxide, TiO_2	0.06
Calcium phosphate, $3CaO.P_2O_5$	0.13
Calcium sulphate, $CaO.SO_3$	0.17
Calcium carbonate, $CaO.CO_2$	72.57
Magnesium carbonate, $MgO.CO_2$	11.08
Manganese carbonate, $MnO.CO_2$	0.11
Water, hydroscopic, H_2O-	0.20
Unbalanced components (excess CO_2, H_2O)	-0.21
Total	99.56

Benwood Limestone

This member consisting of limestone strata separated by calcareous shale partings is prominently developed in Belmont County. A few feet below the base of the Benwood is the Meigs Creek coal and the top of the limestone is marked by a few feet of green shale known as the Fulton Green. The average thickness of this limestone in Belmont County is close to 50 feet. Outcrops are widespread as the horizon is above drainage along the deeper valleys in many townships in this county. The limestone is a gray to bluish gray dense-textured rock and resembles the Fishpot in lithologic character although it generally lacks the regular bedded and persistent nature of the layers which characterize the latter. It has not been utilized to any great extent in Belmont County.

The Benwood limestone and overlying beds are well exposed along a small ravine on the north bank of Glenns Run in the central part of Section 36, Pease Township. A description and measurement of beds exposed here follow:

		Ft.	In.
Limestone, buff, yellowish, marly, Uniontown		5	0
Shale, olive green, Fulton		3	0
Limestone, bluish, tough, impure	Benwood	--	4
Shale and covered	Benwood	3	8
Limestone, bluish, tough, impure	Benwood	1	0
Shale and covered	Benwood	3	2

			Feet	Inches
Limestone, bluish, tough, impure	Benwood (cont.)	....	--	8
Shale, calcareous		....	--	10
Limestone, bluish, and covered................		....	1	11
Shale, yellowish, calcareous, and covered............		....	4	8
Limestone, bluish, dense, sampled		....	4	0
Shale and covered, not sampled		....	1	11
Limestone, bluish gray, somewhat shaly, sampled		....	1	3
Shale, bluish gray, calcareous, not sampled		....	3	2
Limestone, dark bluish gray, dense, sampled		....	1	7
Shale, with a few nodular layers of limestone, not sampled............		....	1	0
Limestone, gray to bluish gray, brecciated, sampled		....	1	8
Shale, calcareous, not sampled............		....	--	11
Limestone, bluish gray, dense, sampled.........		....	3	0
Bottom of exposure.				

The limestone layers of the Benwood occurring below the 4-foot 8-inch bed of marly shale as described in the above section were sampled for chemical analysis on September 16, 1943, by R. E. Lamborn.

Sample No. 421

Chemical analysis of Benwood limestone from outcrop, central Section 36, Pease Township, Belmont County, E. Chadbourn, analyst.

	Per cent
Silica, SiO_2	22.03
Alumina, Al_2O_3	4.42
Ferric oxide, Fe_2O_3	0.61
Ferrous oxide, FeO....................................	1.15
Iron disulphide, FeS_2	0.32
Magnesium oxide, MgO....................................	9.30
Calcium oxide, CaO....................................	27.75
Sodium oxide, Na_2O....................................	0.17
Potassium oxide, K_2O....................................	1.12
Water, hydroscopic, H_2O-....................................	0.61
Water, combined, H_2O+....................................	1.56
Carbon dioxide, CO_2	30.42
Titanium dioxide, TiO_2....................................	0.20
Phosphorus pentoxide, P_2O_5	0.08
Sulphur trioxide, SO_3	0.01
Manganous oxide, MnO....................................	0.06
Total	99.81

The mineral components in Sample No. 421 as calculated (Lamborn) from the chemical analysis follows:

Silica and hydrated aluminum silicates of sodium and potassium	29.20
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.71
Ferrous carbonate, $FeO. CO_2$	1.85
Iron disulphide, FeS_2	0.32
Titanium dioxide, TiO_2	0.20
Calcium phosphate, $3CaO. P_2O_5$	0.17
Calcium sulphate, $CaO. SO_3$	0.02
Calcium carbonate, $CaO. CO_2$	49.35
Magnesium carbonate, $MgO. CO_2$	19.44
Manganese carbonate, $MnO. CO_2$	0.10
Water, hydroscopic, H_2O-	0.61
Unbalanced components (excess CO_2)	-2.16
Total	99.81

Uniontown Limestone

Like the Fishpot and Benwood members previously described, the Uniontown consists of beds of fresh water limestone separated by shales, but the shale beds tend to be thicker and more prominent. The base of the Uniontown is marked by the characteristic Fulton Green shale and the top is separated from the Uniontown coal by a few feet of shale or sandstone. The total average thickness of this limestone-shale series in Belmont County is 41 feet. The distribution of its outcrops includes areas in every township. In general the limestone layers become more numerous and better developed in the eastern part of the county and sandstone and shale become more prominent in the southwestern part. Locally in the eastern part of the county this series is divisible into the Arnoldsburg below and the Uniontown above by a thick and prominent bed of sandstone and sandy shale corresponding to the Arnoldsburg sandstone horizon. Very little economic use is made of the Uniontown limestone member in Belmont County due to the presence of other limestones lower in the section which are of equal quality and contain thinner shale partings. For an analysis of the Uniontown limestone see pages of this report dealing with that member in Monroe County.

Waynesburg Limestone

The Waynesburg limestone "lies directly or closely below the Little Waynesburg coal and from 10 to 25 feet below the Waynesburg coal. The material is of fresh water origin and the deposits typically developed consist of several layers of light-colored limestone separated by partings of light gray shale."[1] The thickness of this member in Belmont County varies from a few inches to as much as 20 feet. It is best represented in Wayne, Washington, York, and Mead townships in the southern part of the county.

Elm Grove Limestone

The Elm Grove limestone is generally present on the outcrop of its horizon in the southern and eastern parts of Belmont County but probably reaches its best development in Washington, York, Pultney, Pease, Mead, and Richland townships. It consists for the most part of one or more layers of dark dense-textured lime-

[1] *Stout, Wilber, The Monongahela series in eastern Ohio: W. V. Acad. Sci. Proc., Vol. 3, p. 132, 1929.*

stone, often laminated in character, separated by beds of calcareous shale. The thickness of the member varies from 1 to 15 feet but the usual measurements are between 3 and 4 feet. The base of the limestone is separated from the top of the Waynesburg coal by a short shale interval usually measuring less than 8 feet in thickness. The Elm Grove limestone has not been utilized in Belmont County for economic needs.

The following is a description of the rock exposures along the National Road in the northeast quarter of Section 21, Richland Township.

		Ft.	In.
Limestone, shaly, ferruginous, and calcareous shale	Elm Grove	1	3
Shale, dark, calcareous	Elm Grove	1	0
Limestone, dark brownish gray, laminated, somewhat siliceous	Elm Grove	1	8
Shale, dark		2	2
Coal and carbonaceous shale, Waynesburg or No. 11		3	4 1/2
Shale and covered		44	11
Coal and carbonaceous shale, Uniontown or No. 10		1	6
Clay, gray, calcareous		4	5
Limestone, gray to brownish gray, Uniontown		1	3

The lower block of the Elm Grove limestone exposed here having a thickness of 1 foot 8 inches was sampled for chemical analysis on September 16, 1943, by R. E. Lamborn.

Sample No. 422

Chemical analysis of Elm Grove limestone from outcrop along National Road, Section 21, Richland Township, Belmont County, E. Chadbourn, analyst.

	Per cent
Silica, SiO_2	5.93
Alumina, Al_2O_3	0.85
Ferric oxide, Fe_2O_3	0.11
Ferrous oxide, FeO	1.05
Iron disulphide, FeS_2	0.99
Magnesium oxide, MgO	0.57
Calcium oxide, CaO	49.19
Sodium oxide, Na_2O	0.08
Potassium oxide, K_2O	0.00
Water, hydroscopic, H_2O-	0.08
Water, combined, H_2O+	0.67
Carbon dioxide, CO_2	39.46
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.08
Sulphur trioxide, SO_3	0.07
Manganous oxide, MnO	0.45
Total	99.59

The mineral composition of Sample No. 422 as determined by calculation (Lamborn) from the chemical analysis is expressed below.

	Per cent
Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.99
$Al_2O_3.2SiO_2.2H_2O$	1.15
Silica, SiO_2	4.93
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.13
Ferrous carbonate, $FeO.CO_2$	1.69
Iron disulphide, FeS_2	0.99
Titanium dioxide, TiO_2	0.01
Calcium phosphate, $3CaO.P_2O_5$	0.17
Calcium sulphate, $CaO.SO_3$	0.12
Calcium carbonate, $CaO.CO_2$	87.54
Magnesium carbonate, $MgO.CO_2$	1.19
Manganese carbonate, $MnO.CO_2$	0.73
Water, hydroscopic, H_2O-	0.08
Unbalanced components (excess CO_2, H_2O)	-0.13
Total	99.59

Mount Morris Limestone

The Mount Morris limestone, the position of which is close below the Waynesburg A coal, is not well represented in Belmont County. A few scattered exposures have been recorded in Washington and Goshen townships,[1] where the member consists of a few thin layers of limestone interstratified with shale presenting trifling economic possibilities.

Lower Washington Limestone

The position of the Lower Washington limestone is close above the Washington coal, the most persistent coal bed in the Permian of Ohio, and about 135 feet above the Waynesburg coal. Like the limestones of the Monongahela it is of the fresh or brackish water type consisting of nodules and layers intermixed with shale. Its known outcrops are best developed in Pease, Pultney, Mead, and Smith townships where the thickness of the series ranges from 1 to 15 feet. Limestone from the Washington horizon has been utilized to a small extent for agricultural lime and for road stone.

A quarry in the Washington limestone owned and operated by A. H. Pickens is located in the south central part of Section 32, Pease Township, at an elevation of approximately 1,210 feet. Here the limestone occurs in good development and purity. The output of the crusher is utilized chiefly for road construction and repair although the fines are marketed for agricultural use. The physical character of the limestone and the succession of beds are described in the following section of exposures in the quarry.

		Ft.	In.
Limestone, bluish gray, dense, sampled	Lower Washington	1	0
Shale, calcareous, not sampled		--	1
Limestone, bluish gray, dense, sampled		--	7
Shale, calcareous, not sampled		--	1

[1] *Stauffer, C. R. and Schroyer, C. R., The Dunkard Series of Ohio: Geol. Survey Ohio, Bull. 22, pp. 66-67, 70-75, 1920.*

			Feet	Inches
Limestone, bluish gray, dense, sampled	Lower Washington (cont.)	....	--	6
Shale, calcareous, not sampled		....	--	1
Limestone, light bluish gray, dense, sampled		....	1	5
Shale, calcareous, not sampled		....	--	2
Limestone, light bluish gray, dense, sampled		....	1	8
Shale, calcareous, not sampled		....	--	2
Limestone, bluish gray, dense, sampled		....	--	3 1/2
Shale, calcareous, not sampled		....	--	11
Limestone, bluish gray, dense, sampled		....	--	6
Limestone, bluish gray, dense, sampled		....	--	5
Limestone, bluish gray, dense, sampled		....	1	4
Shale, calcareous, not sampled		....	--	2
Limestone, bluish gray, dense, sampled		....	1	0
Shale, bluish gray, calcareous, not sampled		....	--	8
Limestone, bluish gray, dense, sampled		....	1	0
Bottom of quarry.				

The limestone layers exposed at this locality having an aggregate thickness of 9 feet 8 inches were sampled for chemical analysis on August 6, 1941, by R. E. Lamborn.

Sample No. 365

Chemical analysis of Washington limestone from quarry of A. H. Pickens, Section 32, Pease Township, Belmont County, Downs Schaaf, analyst.

	Per cent
Silica, SiO_2	4.82
Alumina, Al_2O_3	0.86
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.70
Iron disulphide, FeS_2	0.03
Magnesium oxide, MgO	0.75
Calcium oxide, CaO	50.86
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.08
Water, hydroscopic, H_2O-	0.29
Water, combined, H_2O+	0.25
Carbon dioxide, CO_2	41.09

Titanium dioxide, TiO_2	0.07
Phosphorus pentoxide, P_2O_5	0.12
Sulphur trioxide, SO_3	0.02
Manganous oxide, MnO	0.11
Carbon, organic, C	0 08
Hydrogen, organic, H	--
Total	100.17

The per cent of each of the compounds present in Sample No. 365 has been computed (Lamborn) from the chemical analysis with results as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.92
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.27
Silica, SiO_2	3.81
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.13
Iron disulphide, FeS_2	0.03
Titanium dioxide, TiO_2	0.07
Calcium phosphate, $3CaO.P_2O_5$	0.26
Calcium sulphate, $CaO.SO_3$	0.03
Calcium carbonate, $CaO.CO_2$	90.50
Magnesium carbonate, $MgO.CO_2$	1.57
Manganese carbonate, $MnO.CO_2$	0.18
Water, hydroscopic, H_2O-	0.29
Organic matter	0.08
Unbalanced components (deficiency CO_2, H_2O)	+0.01
Total	100.17

Middle and Upper Washington Limestones

Like the Lower Washington the Middle and Upper Washington limestones are made up of nodules or layers of the fresh or brackish water type embedded in clay shales. The position of these limestones is in the upper part of the Washington group, below the Jollytown A coal and above the Lower Washington limestone. According to Stauffer and Schroyer, outcrops of these limestones are found in Pease, Colerain, Pultney, Richland, Smith, Mead, Washington, and Wayne townships. Limestone belonging to one of these members has been crushed near Kelsey, Smith Township, for agricultural lime.

CARROLL COUNTY

General Considerations

Carroll County comprises an area of 398 square miles located in the maturely dissected Appalachian Plateau of eastern Ohio, just south of the border of continental glaciation. The bedrocks which reach the surface in this county belong to the Allegheny and Conemaugh series of the Pennsylvanian system and include those strata which occur in this region between the Brookville or No. 4 coal and the Pittsburgh or No. 8 coal. The outcrops of the Allegheny series are confined in their distribution to the lower slopes along the major valleys in the northwestern half of the county. As the regional dip is to the southeast, these beds pass in that direction beneath overlying beds of Conemaugh age, which comprise the surface strata in the southeastern half of the area. The total thickness of the bedrock series outcropping across Carroll County is approximately 620 feet. A generalized section of the beds exposed as recorded by Condit[1] and Lamborn[2] is as follows:

Generalized Section of Bedrocks Outcropping in Carroll County

	Ft.	In.
Pennsylvanian system		
Monongahela series		
Pittsburgh or No. 8 coal	--	--
Conemaugh series		
Clay with nodules and layers of gray limestone, Pittsburgh	9	0
Shale, sandy	22	0
Clay and clay shale with layers and nodules of limestone, Summerfield	36	0
Sandstone, shaly, varying to sandy shale, Connellsville	30	0
Clay and clay shale, nodular limestone, and red beds common	28	0
Sandstone, somewhat massive, conglomeratic at base, Morgantown	40	0
Iron ore, fossiliferous, Skelley limestone horizon	--	--
Coal blossom, thin, Duquesne	--	1
Clay, calcareous	--	6
Shale, gray, with red clay shale layers	14	0
Limestone, gray, crystalline, fossiliferous, conglomeratic in places, Ames	2	0
Shale, generally gray	14	0
Coal, Harlem	2	0
Shale, generally red; sandstone in places, Round Knob shale region	28	0
Coal, Barton	1	6
Clay, calcareous, with layers and nodules of limestone, Ewing	28	0
Shale, sandy	37	0
Shale, fossiliferous, Portersville limestone horizon	3	0
Coal, thin, Anderson	--	--
Shale, with an occasional yellow limestone nodule	12	0
Limestone, ferruginous, somewhat nodular, fossiliferous, discontinuous, Cambridge	--	6
Coal, thin, Wilgus	--	--
Clay, calcareous	3	0
Sandstone, coarse, massive, local, grading laterally into shale, Buffalo	38	0
Shale, dark, calcareous, fossiliferous. Black nodular limestone is sometimes present, Brush Creek limestone horizon	4	0
Shale, sandy	18	0
Coal, thin, local, Mason	--	--
Clay	4	0
Shale, carbonaceous	--	7
Shale, gray	1	10
Coal, Mahoning	1	8

[1] *Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17, pp. 211-212, 1912.*

[2] *Lamborn, R. E., The coal beds of western Carroll County: Geol. Survey Ohio Bull. 43, p. 9, 1942.*

Clay, gray, plastic		4	7
Sandstone, local, grading laterally to sandy shale, Mahoning sandstone horizon		23	3
Allegheny series			
Coal	Upper Freeport or No. 7	2	5 1/2
Parting		-	1 1/4
Coal		-	11
Clay, gray, arenaceous		8	8
Limestone, discontinuous, nodular in places, Upper Freeport		1	10
Clay, flinty, discontinuous, Boliver		6	0
Sandstone and shale, Upper Freeport		33	0
Coal	Lower Freeport or No. 6a	1	6
Parting		-	1
Coal		-	10
Clay, impure		5	0
Sandstone, local, grading laterally to shale, Lower Freeport sandstone horizon		39	10
Coal	Middle Kittanning or No. 6	1	4 1/2
Parting		-	1
Coal		1	7
Clay, dark blue, arenaceous		5	0
Sandstone and shale		36	6
Coal	Lower Kittanning or No. 5	1	4
Sulphur band		-	1
Coal		1	8
Clay, generally plastic, with a bed of flint clay near the middle		11	6
Shale, bluish gray, with some iron carbonate nodules near base		45	0
Limestone, bluish to brownish gray, Putnam Hill		3	0
Shale, dark, soft		-	6
Coal	Brookville or No. 4	1	0
Parting		-	1
Coal		1	1

As indicated in the general section, ten distinct limestone horizons have been recognized in the series exposed in Carroll County but the members are by no means thick or persistent and continuous on the outcrop. The Upper Freeport, Ewing, Summerfield, and Pittsburgh limestones, being of fresh or brackish water origin, consist for the most part of local deposits of nodular or lens-like limestone layers embedded in calcareous clays and shales and have trifling economic value. The marine horizons are represented by the Putnam Hill, Brush Creek, Cambridge, Portersville, Ames, and Skelley. Of these only the Putnam Hill and Ames limestones occur locally in sufficient purity or in thick enough development to merit interest as sources of limestone for economic use.

No thick deposits of limestone are encountered below drainage at depths less than 2,000 feet below tide.

Putnam Hill Limestone

Outcrops of Putnam Hill limestone in Carroll County are confined to the valley of Sandy Creek in the northwest corner of Rose Township and to the valley of Huff Run near Lindentree, also in Rose Township. Good exposures of the Putnam Hill limestone occur in the strip pit of the Whitacre-Greer Fireproofing Company located in the northwest quarter of Section 36. The limestone is wasted in mining the Brookville clay. The various beds exposed here are described below.

	Ft.	In.
Shale, bluish gray, weathered	12	0
Shale, bluish gray, with ore nodules	4	0
Limestone, bluish to brownish gray, dense, fossiliferous, one bed	2	11
Limestone, bluish to brownish gray, dense, fossiliferous, one bed	-	6
Shale, soft, dark, carbonaceous	-	7
Coal (Brookville or No. 4)	1	0
Parting (Brookville or No. 4)	-	1
Coal (Brookville or No. 4)	1	1
Clay, plastic, purplish	3	8
Sandstone, gray, micaceous, clay bond, varies from 2 to 6 feet	4	0
Clay, gray, micaceous, arenaceous	11	0
Bottom of pit.		

The Putnam Hill limestone exposed in this pit and having a thickness of 3 feet 5 inches was sampled for chemical analysis by R. E. Lamborn on May 20, 1941.

Sample No. 332

Chemical analysis of Putnam Hill limestone from pit of Whitacre-Greer Fireproofing Company near Magnolia, Carroll County, Downs Schaaf, analyst.

	Per cent
Silica, SiO_2	5.34
Alumina, Al_2O_3	2.20
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.93
Iron disulphide, FeS_2	0.47
Magnesium oxide, MgO	1.07
Calcium oxide, CaO	48.70
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.03
Potassium oxide, K_2O	0.10
Water, hydroscopic, H_2O-	0.22
Water, combined, H_2O+	0.59
Carbon dioxide, CO_2	39.88
Titanium dioxide, TiO_2	0.10
Phosphorus pentoxide, P_2O_5	0.18
Sulphur trioxide, SO_3	0.03
Manganous oxide, MnO	0.20
Carbon, organic, C	0.03
Hydrogen, organic, H	----
Total	100.09

The percent of each of the various compounds probably present in Sample No. 332 has been computed (Lamborn) from the chemical analysis.

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.21
Hydrated silicates $Al_2O_3.2SiO_2.2H_2O$	4.38
Silica, SiO_2	2.74
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.50

Iron disulphide, FeS_2	0.47
Titanium dioxide, TiO_2	0.10
Calcium phosphate, $3CaO.P_2O_5$	0.39
Calcium sulphate, $CaO.SO_3$	0.05
Calcium carbonate, $CaO.CO_2$	86.50
Magnesium carbonate, $MgO.CO_2$	2.24
Manganese carbonate, $MnO.CO_2$	0.33
Water, hydroscopic, H_2O-	0.22
Organic matter	0.03
Unbalanced components (excess CO_2, H_2O)	-0.09
Total	100.09

Ames Limestone

The horizon of the Ames limestone has a wide distribution on the outcrop in the southeastern half of Carroll County but the limestone lacks continuity and at many places where it does occur it is thin. This member is generally present near the hilltops at altitudes ranging from 1,200 to 1,275 feet in northwestern Orange and western Perry townships; in Union, western Lee, and southeastern Washington townships; and in Fox Township. In eastern Perry Township and western Loudon Township it is generally wanting on the outcrop. As usually found on the outcrop in Carroll County, the Ames varies in thickness from a few inches to about one foot, but locally it occurs in much better development. Near Harlem Springs, Fox Township, this limestone, about one foot in thickness, is reported to have been quarried on a small scale and pulverized for agricultural use. The Ames has an unusual development in the northeast quarter of Section 14, Center Township, where it outcrops at an altitude of about 1,260 feet. Here the stone was formerly quarried and crushed for road materials. Prior to 1935 the Ames limestone was quarried on a small scale and pulverized for agricultural use on the Lida Graham property at Scroggsfield, Fox Township. The limestone was secured by stripping along the outcrop around the high hill located just north of the village in the west central part of Section 26. A description of the stone exposed in 1941 is given below.

		Ft.	In.
Soil		1	0
Limestone, light brownish gray, crystalline, fossiliferous, one bed	Ames	1	10
Limestone, light brownish gray, crystalline, fossiliferous, one bed	Ames	1	8
Bottom of excavation.			

The Ames limestone exposed at this locality and described in the above section was sampled by R. E. Lamborn on July 30, 1941, for chemical analysis.

Sample No. 360

Sample of Ames limestone from abandoned quarry on the Lida Graham property near Scroggsfield, Fox Township, Carroll County, Downs Schaaf, analyst.

	Per cent
Silica, SiO_2	6.50
Alumina, Al_2O_3	1.18
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.38
Iron disulphide, FeS_2	0.08

Magnesium oxide, MgO	0.74
Calcium oxide, CaO	49.84
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.03
Potassium oxide, K_2O	0.10
Water, hydroscopic, H_2O-	0.23
Water, combined, H_2O+	0.29
Carbon dioxide, CO_2	40.10
Titanium dioxide, TiO_2	0.05
Phosphorus pentoxide, P_2O_5	0.15
Sulphur trioxide, SO_3	0.09
Manganous oxide, MnO	0.25
Carbon, organic, C	0.02
Hydrogen, organic, H	----
Total	100.05

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.22
Hydrated silicates $Al_2O_3.2SiO_2.2H_2O$	1.79
Silica, SiO_2	5.11
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeCO_3$	0.61
Iron disulphide, FeS_2	0.08
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO.P_2O_5$	0.33
Calcium sulphate, $CaO.SO_3$	0.15
Calcium carbonate, $CaO.CO_2$	88.53
Magnesium carbonate, $MgO.CO_2$	1.55
Manganese carbonate, $MnO.CO_2$	0.40
Water, hydroscopic, H_2O-	0.23
Organic matter	0.02
Unbalanced components (excess CO_2, H_2O)	-0.04
Total	100.05

COLUMBIANA COUNTY

General Considerations

The bedrocks outcropping in Columbiana County belong to the upper part of the Pottsville series, the Allegheny series, and the lower four-fifths of the Conemaugh series. The total thickness of the beds exposed in this area is approximately 755 feet. Outcrops of bedrock are widespread but they are less frequent in the northern half of the county where continental glaciation has subdued the topography by filling up many valleys and burying the rock hills to some extent with deposits of glacial drift. South of the drift border, represented roughly by an east-west line passing through Kensington, Hanover Township, the rugged character of the topography, characteristic of the unglaciated part of the Allegheny Plateau, yields many natural rock outcrops. In general the lowest beds in the series exposed reach the surface near water level in the valleys of the Ohio River and Little Beaver River along the eastern and southeastern edge whereas the highest members form the hilltops in the southern part of Wayne Township in the south central part of the county.

Eleven limestone horizons occur in the rock series outcropping in Columbiana

County. These include the Clarksburg, Ames, Cambridge, Brush Creek, Mahoning, Upper Freeport, Lower Freeport, Salem, Hamden, Vanport, and Upper Mercer. In general these limestones are usually thin and patchy in distribution in this county. Their combined average thickness is approximately one per cent of the total thickness of beds exposed. Locally the most prominent members have been utilized in a small way for limestone for agricultural needs. The stratigraphic position of the various limestone members in Columbiana County is indicated in the following generalized section:[1]

Generalized Section of Bedrocks Outcropping in Columbiana County

	Ft.	In.
Pennsylvanian system		
Conemaugh series		
Sandstone, massive, coarse-grained, Connellsville	40	0
Shale, pink to gray	27	0
Shale, pink, with nodular limestone, Clarksburg horizon	3	0
Shale, mostly pink	20	0
Sandstone, massive, coarse-grained, Morgantown	20	0
Shale, mostly pink	30	0
Limestone, fossiliferous, locally ferruginous, Ames	1	4
Shale, gray to red	12	0
Coal, local, Harlem	--	10
Clay, arenaceous	1	0
Shale, pink to red and mottled, Round Knob	32	0
Shale, arenaceous, with thin shaly sandstone	54	0
Coal, shaly, Anderson	1	0
Clay, arenaceous, impure	2	0
Shale, gray, arenaceous	12	0
Limestone, fossiliferous, gray to brown, usually ferruginous, Cambridge	1	2
Shale, gray to dark	4	10
Coal, locally present, Wilgus	--	10
Clay, gray, arenaceous	1	0
Shale, gray, sandy, with thin sandstones	62	4
Shale, dark, fossiliferous, locally with dark, nodular, fossiliferous limestone in lower or middle portions, Brush Creek horizon	12	0
Shale, dark, carbonaceous	1	3
Coal, shaly, locally present, Brush Creek	--	7
Clay, gray, arenaceous	2	6
Shale and sandstone	19	8
Coal, shaly, usually wanting, Mason	--	1
Clay, gray, olive or pink	5	5
Sandstone, soft, micaceous, locally present, Upper Mahoning	15	0
Shale, gray, arenaceous	9	0
Shale, dark, carbonaceous, locally fossiliferous	--	8
Coal, variable in thickness, Mahoning	1	10
Clay, gray, plastic	5	0
Limestone, nodular, Mahoning	1	0

[1] *Stout, Wilber, and Lamborn, R. E., Geology of Columbiana County: Geol. Survey Ohio Bull. 28, 1924.*

Shale, argillaceous to arenaceous, gray	10	0
Sandstone, locally present, Lower Mahoning	22	0
Shale, gray, arenaceous	4	0
Shale, dark, locally fossiliferous	1	0
Allegheny series		
Coal } Upper Freeport or No. 7	2	8
Shale, parting } Upper Freeport or No. 7	--	2
Coal } Upper Freeport or No. 7	--	5
Clay, plastic	6	7
Limestone, local, Upper Freeport	3	8
Coal, seldom present	--	3
Clay, flint and plastic, unsteady, Bolivar	6	0
Sandstone, locally present, Upper Freeport	15	0
Shale, arenaceous	23	0
Coal } Lower Freeport or No. 6a	--	8
Shale } Lower Freeport or No. 6a	--	1
Coal } Lower Freeport or No. 6a	--	9
Clay, gray, plastic	4	5
Limestone, unsteady, Lower Freeport	1	7
Clay, flint and plastic	5	7
Shale, arenaceous	8	0
Sandstone, locally developed, Lower Freeport	25	0
Shale, arenaceous	6	0
Coal, very unsteady, Upper Kittanning	--	8
Clay, impure	1	5
Shale, with ore nodules	10	0
Shale, bony, fossiliferous, Washingtonville	2	2
Shale, dark	4	6
Coal, good } Middle Kittanning or No. 6	1	7
Coal, bony } Middle Kittanning or No. 6	--	1
Clay, arenaceous	4	10
Limestone, impure, fresh water, Salem	--	8
Clay, part flint, Oak Hill	6	5
Shale, arenaceous	17	2
Shale and limestone, Hamden	1	10
Coal, steady, Lower Kittanning or No. 5	2	1
Clay, plastic, good	8	0
Shale, arenaceous	15	0
Sandstone, Lower Kittanning, or No. 5	20	0
Shale, very arenaceous	29	0
Shale, black, very fossiliferous } Vanport	1	1
Shale, gray, in places fossiliferous } Vanport	5	8
Limestone, dark, impure, fossiliferous } Vanport	--	8
Shale, gray, in places fossiliferous } Vanport	8	11
Coal, impure, Clarion or No. 4a	--	8
Clay, arenaceous	7	3
Shale, arenaceous	8	0
Coal, shaly, Brookville or No. 4	1	0
Pottsville series		
Clay, arenaceous	2	3
Shale, arenaceous	8	0
Coal and coaly shale, Tionesta or 3b	--	6
Clay, arenaceous	1	0

Shale and shaly sandstone	14	0
Limestone, blue, fossiliferous, Upper Mercer	--	7
Shale, calcareous, fossiliferous	--	4
Clay shale	3	0
Shale, arenaceous	12	0
Sandstone, massive	8	0

Upper Mercer Limestone

The Upper Mercer limestone has no economic importance in Columbiana County as its outcrops are confined to the Little Beaver Valley in St. Clair Township where it measures one foot or less in thickness and where it is siliceous and ferruginous in composition.

Vanport Limestone

Although the Vanport member yields much stone in eastern Mahoning County and in Vinton, Jackson, and Lawrence counties, it is poorly developed in Columbiana County. Where outcrops occur along the valleys of North Fork and Middle Fork and along the Ohio Valley it consists of a foot or so of impure limestone embedded in fossiliferous shales.

Hamden Limestone

The Hamden member which is found in many places closely overlying the Lower Kittanning coal has trifling economic importance in this county. Limestone is only local in its occurrence and where present it consists for the most part of small nodular masses embedded in fossiliferous shales.

Salem Limestone

The Salem limestone member occurring close above the Oak Hill clay in this county has little potential value as a source of limestone. On its outcrop, which extends along the valley of Middle Fork from Teegarden to Elkton, along West Fork in Madison Township, and along the North Fork of Yellow Creek, this member is either an impure limestone a foot or less in thickness or an iron carbonate ore. The following record was secured at the mine of the Salem Mining Co. located in the northwestern part of Section 3, Salem Township.[1]

	Ft.	In.
Coal blossom, Middle Kittanning	1	0
Shale and shaly sandstone	10	0
Limestone, dark, blocky, Salem	--	8
Shale, gray, parts covered	36	0
Coal, Lower Kittanning	3	4

In order to show its chemical character the Salem member was sampled at this locality by Myron T. Sturgeon for analysis.

Sample No. 441

Chemical analysis of Salem limestone from outcrop at mine of Salem Mining

[1] *Stout, Wilber, and Lamborn, R. E., op cit., p. 147.*

Company, Section 3, Salem Township, Columbiana County, Nalin Laboratories, analysts.

	Per cent
Silica, SiO_2	4.07
Alumina, Al_2O_3	2.39
Ferric Oxide, Fe_2O_3	1.90
Ferrous oxide, FeO	11.57
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	3.66
Calcium oxide, CaO	37.08
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.22
Potassium oxide, K_2O	0.35
Water, hydroscopic, H_2O-	0.18
Water, combined, H_2O+	0.05
Carbon dioxide, CO_2	36.70
Titanium dioxide, TiO_2	0.04
Phosphorus pentoxide, P_2O_5	0.32
Sulphur trioxide, SO_3	0.14
Manganous oxide, MnO	0.30
Carbon, organic, C	1.11
Hydrogen, organic, H	0.21
Total	100.29

The per cent of each of the compounds probably present in the sample has been calculated (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	6.87
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.43
Silica, SiO_2	1.25
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	2.22
Ferrous carbonate, $FeO.CO_2$	18.65
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.04
Calcium phosphate, $3CaO.P_2O_5$	0.70
Calcium sulphate, $CaO.SO_3$	0.24
Calcium carbonate, $CaO.CO_2$	65.33
Magnesium carbonate, $MgO.CO_2$	7.65
Manganese carbonate, $MnO.CO_2$	0.49
Water, hydroscopic, H_2O-	0.18
Organic matter	1.32
Unbalanced components (excess CO_2, H_2O)	-5.08
Total	100.29

Lower Freeport Limestone

The field of outcrops of Lower Freeport limestone in this county includes much of the northern glaciated portion, where the drift is thick and the rock exposures few in number, and parts of every township in the southern unglaciated part except Wayne and Franklin. Over this field the limestone is notably patchy in distribution. Where present its thickness ranges from a few inches to about 5 feet but averages about 1 foot 7 inches. This limestone is probably best developed in Center, Elk Run, and northern Madison townships. The stone was formerly worked on a small scale in Section 17, Elk Run Township, where it was crushed for agricultural purposes. It has likewise been utilized near Lisbon in the production of hydraulic cement. A description of the beds exposed in the old mines of the Ohio Cement Company in Section 9, Center Township, is given below:

	Ft.	In.
Coal, thin, irregular, Lower Freeport	--	2
Clay, plastic	4	0
Shale	4	0
Shale, calcareous, with some limestone, Lower Freeport	2	2

The beds formerly utilized at this locality consisting of limestone and calcareous shale were sampled by C. F. Moses in 1921.[1]

Sample No. 1000

Chemical analysis of Lower Freeport limestone and calcareous shale from mines of Ohio Cement Company, Section 9, Center Township, Columbiana County, D. J. Demorest, analyst.

	Per cent
Silica, SiO_2	13.80
Alumina, Al_2O_3	7.00
Ferric oxide, Fe_2O_3	4.55
Calcium oxide, CaO	38.35
Magnesium oxide, MgO	1.32
Phosphorus pentoxide, P_2O_5	0.248
Sodium oxide, Na_2O	2.61
Potassium oxide, K_2O	0.86
Manganous oxide, MnO	0.29
Sulphur, S	none

Upper Freeport Limestone

The Upper Freeport limestone, like the Lower Freeport which it closely resembles in lithologic characteristics, is of widespread occurrence in Columbiana County, but it is patchy in distribution and variable in thickness on the outcrop. Exposures of this member occur in every township in the county but they are few in the northern part due to widespread deposits of glacial drift. The limestone occurs in good development at a number of localities along the valley of Middle Fork in Center Township, along the West Fork in northern Madison and eastern Hanover townships, and along the valleys tributary to the Ohio River in southern Yellow Creek Township. The thickness of the member varies from a few inches to 20 feet or more with an average thickness a little in excess of 3 feet. Where a-greater-than-average thickness occurs, the member consists of limestone beds interstratified with shale.

Small quantities of Upper Freeport limestone have been quarried in the southwest part of Section 30, Butler Township, where the stone has been calcined for agricultural use. This member has likewise been utilized near Lisbon in Center Township where the stone occurs in exceptional thickness. The following is a record of the exposures at the mines of the Lisbon Lime Company, located just southwest of Lisbon.[2]

	Ft.	In.
Coal blossom Upper Freeport or No. 7	1	0

[1] *Stout, Wilber, and Lamborn, R. E., op. cit., p. 195.*

[2] *Stout, Wilber, and Lamborn, R. E., op. cit., p. 222.*

Sandstone, shaly		2	0
Shale, gray		5	0
Limestone, nodular, ferruginous	Upper Freeport	--	6
Shale, gray	Upper Freeport	--	6
Limestone, with partings	Upper Freeport	3	0
Shale, gray	Upper Freeport	--	8
Limestone, irregular	Upper Freeport	1	0
Shale, calcareous, arenaceous	Upper Freeport	1	6
Shale, gray	Upper Freeport	--	8
Limestone, massive	Upper Freeport	3	6
Shale, arenaceous, calcareous	Upper Freeport	2	0
Limestone, irregular	Upper Freeport	1	3
Limestone, irregular	Upper Freeport	--	8
Covered interval		56	0
Coal, Lower Freeport reported thickness		1	8

At the locality described above, the Upper Freeport limestone was formerly worked by the Lisbon Lime Company and the stone was prepared for agricultural uses both by pulverizing and by calcination. The limestone at this locality was sampled for chemical analysis in 1921 by C. F. Moses. [1]

Sample No. 1001

Chemical analysis of Upper Freeport limestone from quarry of Lisbon Lime Company at Lisbon, Center Township, Columbiana County, D. J. Demorest, analyst.

	Per cent
Silica, SiO_2	15.40
Alumina, Al_2O_3	4.47
Ferric oxide, Fe_2O_3	1.99
Calcium oxide, CaO	42.10
Magnesium oxide, MgO	0.91
Manganous oxide, MnO	0.11
Phosphorus pentoxide, P_2O_5	0.139
Potassium oxide, K_2O	0.52
Sodium oxide, Na_2O	0.22
Sulphur, S	none

Calculated from the analysis the per cent of each of the different inorganic compounds present in such a limestone is approximately as follows:

Mica, $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	7.13
Kaolin, $Al_2O_3.2SiO_2.2H_2O$	4.25
Silica, SiO_2	10.15
Calcium phosphate, $3CaO.P_2O_5$	0.31
Calcium carbonate, $CaO.CO_2$	74.88
Magnesium carbonate, $MgO.CO_2$	1.91
Manganese carbonate, $MnO.CO_2$	0.18
Ferrous carbonate, $FeO.CO_2$	2.88
Total	101.69

[1] *Stout, Wilber, and Lamborn, R. E., op. cit., pp. 225-226.*

Mahoning Limestone

Outcrops of the horizon of the Mahoning limestone, which lies a few feet below the Mahoning coal, are widely distributed in Columbiana County but the limestone is generally thin and nodular and, lacking continuity, is wanting in many places. It is probably best developed over small areas in Elk Run and Washington townships where it consists of one or more somewhat irregular layers of arenaceous limestone embedded in shales and calcareous clays. Little economic importance can be attached to this member.

Brush Creek Member

The Brush Creek member in Columbiana County occurs about 100 feet above the Upper Freeport coal. Its outcrops are widely distributed in St. Clair, West, Hanover, Center, Elk Run, Liverpool, Yellow Creek, Madison, Middleton, Wayne, Franklin, and Washington townships. The member consists in this area in large part of black fossiliferous shale "through which nodules of black fossiliferous limestone are irregularly distributed or are locally concentrated into one or two layers in the basal part of the shale."[1] The limestone is a comparatively thin element in the member and has trifling economic importance.

Cambridge Limestone

Although the Cambridge limestone outcrops over a broad area in Columbiana County embracing parts of Hanover, Franklin, Washington, Wayne, Madison, and St. Clair townships, the largest area and thickest deposits are found in Madison Township. Observations made in the field indicate a thickness for the Cambridge on the outcrop ranging from 1 foot 2 inches to about 2 feet 11 inches and an average position about 180 feet above the Upper Freeport coal. The stone ranges from dark gray fossiliferous limestone to a rock which is highly siliceous to highly ferruginous. The following is a description of the rock exposures at Round Knob in Section 22, Madison Township, where the Cambridge limestone is at its best in this county.

	Ft.	In.
Summit, Round Knob, altitude, 1,447 feet	--	--
Sandstone, massive, coarse-grained, Morgantown	61	0
Shale and covered	17	0
Limestone, Ames	1	0
Shale, red, with some gray layers interbedded	78	0
Shale, gray, with nodules of limestone at base	53	0
Coal blossom and black shale, Anderson	1	0
Clay and covered	2	0
Shale, sandy, and shaly sandstone	12	6
Limestone, gray, fossiliferous, Cambridge	2	11
Shale, gray, and covered	20	0
Covered interval	53	0
Shale, Brush Creek	3	0

A sample of Cambridge limestone was secured at Round Knob by C. F. Moses in 1921 for chemical analysis.[2]

[1] *Stout, Wilber, and Lamborn, R. E., op. cit. p. 323.*

[2] *Stout, Wilber, and Lamborn, R. E., op. cit., pp. 340-341.*

Sample No. 1002

Chemical analysis of Cambridge limestone from Round Knob, Madison Township, Columbiana County, D. J. Demorest, analyst.

	Per cent
Silica, SiO_2	6.20
Alumina, A_2O_3	2.39
Ferric oxide, Fe_2O_3	1.34
Calcium oxide, CaO	49.50
Magnesium oxide, MgO	0.91
Manganous oxide, MnO	0.39
Phosphorus pentoxide, P_2O_5	0.47
Sulphur, S	none

Calculated from the analysis the per cent of each of the compounds present in the sample is approximately as follows:

Kaolin, $Al_2O_3.2SiO_2.2H_2O$	6.04
Silica, SiO_2	3.39
Calcium phosphate, $3CaO.P_2O_5$	0.47
Calcium carbonate, $CaO.CO_2$	87.93
Magnesium carbonate, $MgO.CO_2$	1.90
Manganese carbonate, $MnO.CO_2$	0.63
Ferrous carbonate, $FeO.CO_2$	1.94

Ames Limestone

The distribution of the Ames limestone in Columbiana County is confined to small areas underlying the high knobs and ridges in Madison, Yellow Creek, Washington, Wayne, and Franklin townships. The limestone is not equally well developed over this field, however, as it tends to be patchy in distribution in Wayne and Franklin townships and highly ferruginous in Washington Township. It probably reaches its best state of development in Madison and southern Yellow Creek townships where for the most part it is a greenish gray, crystalline limestone of good purity. Field measurements show variations in thickness ranging from 1 foot 4 inches to 2 feet 1 inch.

The following is a record of outcrops in the north central part of Section 21, Madison Township:

		Ft.	In.
Shale, red		5	0
Limestone, gray, fossiliferous, one layer	Ames	1	0
Limestone, gray, fossiliferous, one layer	Ames	1	1
Clay, red and yellow		5	0

The Ames limestone at this locality having a thickness of 2 feet 1 inch was sampled by C. F. Moses in 1921 for chemical analysis.[1]

Sample No. 1003

Chemical analysis of Ames limestone from outcrop in Section 21, Madison

[1] *Stout, Wilber, and Lamborn, R. E., op. cit. p. 352.*

Township, Columbiana County, D. J. Demorest, analyst.

	Per cent
Silica, SiO_2	3.90
Alumina, Al_2O_3	1.34
Ferric oxide, Fe_2O_3	1.82
Calcium oxide, CaO	51.00
Magnesium oxide, MgO	0.87
Manganous oxide, MnO	0.439
Phosphorus pentoxide, P_2O_5	0.093
Sulphur, S	0.426

Expressed in terms of the per cent of each of the compounds probably present in the sample, the composition is as follows:

Kaolin, $Al_2O_3 . 2SiO_2 . 2H_2O$	3.39
Silica, SiO_2	2.32
Calcium phosphate, $3CaO. P_2O_5$	0.20
Calcium carbonate, $CaO. CO_2$	90.89
Magnesium carbonate, $MgO. CO_2$	1.82
Manganese carbonate, $MnO. CO_2$	0.71
Ferrous carbonate, $FeO. CO_2$	1.87
Iron disulphide, FeS_2	0.80

Clarksburg Limestone

The distribution of the outcrops of Clarksburg limestone in Columbiana County is confined to a few high hills in Wayne Township. Here the member has no economic importance as it consists of thin nodular limestone embedded in calcareous clay.

COSHOCTON COUNTY

General Considerations

Coshocton County, having an area of 567 square miles, embraces that small part of the Appalachian Plateau of eastern Ohio immediately surrounding the confluence of the Tuscarawas and Walhonding rivers to form the southern-flowing Muskingum River. Here the mature dissection of the land surface and the general absence of glacial drift except along the western margin lead, in general, to a large and widely distributed number of outcrops. The bedrocks exposed in this county have a vertical thickness of about 610 feet and include strata of both Mississippian and Pennsylvanian ages. The bedrocks consist chiefly of sandstone and shale with minor amounts of coal, clay, and limestone. The aggregate thickness of the various limestone members, all of which belong to the Pennsylvanian, is approximately one per cent of the thickness of the series exposed. The sandstones and shales comprising the Mississippian beds outcrop in general along the lower slopes in the western third of the area. From the outcrop they dip in a general southeastern direction beneath the younger and overlying Pennsylvanian. This direction of dip is maintained to the axis of the Parkersburg-Lorain syncline, which can be represented approximately by a straight line extending through Coshocton and Millersburg. From this axis the surface beds rise sharply and irregularly to the east, forming the western rim of the Cambridge arch beyond which the general southeastern dip is gentle and irregular to the eastern boundary of the county. A general section of the rocks exposed based upon much field data secured by the writer in parts of the county and on some data collected by Mr. Ralph Meyers in Jefferson and Bedford townships is given below:

Generalized Section of Bedrock Outcropping in Coshocton County

Pennsylvanian system	Ft.	In.
Conemaugh series		
Sandstone and shale	120	0
Allegheny series		
Coal, thin, discontinuous, Upper Freeport or No. 7	1	0
Clay, gray, calcareous	3	0
Sandstone, grading laterally to arenaceous shale	75	0
Middle Kittanning or No. 6:		
Shale, black, and shaly coal	-	5
Coal, good	2	8
Clay shale parting	-	1 1/4
Coal, good	-	9
Clay, bluish gray, arenaceous	5	3
Shale, dark bluish gray, arenaceous	24	4
Shale, dark, carbonaceous, fossiliferous	4	0
Coal, Lower Kittanning or No. 5	2	2
Clay, gray, plastic	5	11
Shale, bluish gray, arenaceous	15	8
Iron ore, local, Ferriferous	-	2
Limestone, gray to bluish gray, dense to crystalline; replaced locally by white to variegated chert, Vanport	2	3
Shale, carbonaceous, discontinuous	-	4
Coal and black shale, locally developed, Clarion or No. 4a	1	0
Clay, gray, locally present	5	0
Sandstone, local, Clarion, grades laterally to bluish gray, arenaceous shale	24	10
Limestone, bluish gray, fossiliferous, generally dense-textured, locally with chert, Putnam Hill	2	1
Shale, dark, carbonaceous, discontinuous	-	5
Coal, shaly, Brookville or No. 4	1	1
Pottsville series		
Clay, gray, plastic	5	1
Sandstone, local, Homewood, grading laterally to arenaceous shale	15	11
Coal, local in occurrence, Tionesta or No. 3b	-	7
Clay, gray, plastic	4	1
Shale and sandstone	19	7
Upper Mercer:		
Limestone, black, dense-textured, fossiliferous, ferruginous, flinty, discontinuous	-	6
Shale, bluish gray, local	6	0
Limestone, black, fossiliferous, dense-textured, with much black flint	1	10
Shale, dark, carbonaceous, discontinuous	-	2
Coal, shaly, impure, Bedford	-	10
Clay, gray, plastic	5	1

Shale, bluish gray, arenaceous	5	0
Coal, locally present, Upper Mercer or No. 3a	-	10
Clay, bluish gray, locally present	3	0
Shale, bluish gray, arenaceous	13	10
Limestone, dark bluish gray, fossiliferous, Lower Mercer	2	3
Coal, shaly, and black shale, Middle Mercer	-	10
Clay, gray, plastic	7	0
Shale, gray, sandy	12	0
Limestone, gray, fossiliferous, local in occurrence, Boggs	-	6
Shale, bluish gray	5	0
Coal, discontinuous, Lower Mercer or No. 3	-	2
Clay, gray, plastic	2	9
Sandstone and arenaceous shale	12	0
Limestone, ferruginous, Poverty Run	-	3
Shale	-	6
Coal, shaly, discontinuous, Vandusen	-	6
Clay	1	0
Shale, bluish gray, arenaceous	17	0
Coal, shaly, and black shale, locally present, Bear Run	-	4
Clay, gray	1	0
Sandstone, medium-grained, massive, Massillon	25	0
Coal and black shale, Quakertown or No. 2	-	3
Clay, gray	11	0
Sandstone, shaly	10	0
Coal and black shale, locally present, Anthony	-	4
Clay, light-colored, arenaceous, Sciotoville	5	0
Sandstone, heavy-bedded to shaly	12	0
Black shale and shaly coal, locally present, Sharon or No. 1	2	8
Sandstone, coarse-grained, conglomeratic, Sharon	20	0
Ore, sandy, Harrison	1	0
Mississippian system		
Sandstone and shale undivided, Logan formation	200	0

Six limestone members occur in the rock series exposed at the surface in Coshocton County. Of these the Putnam Hill and Lower Mercer members have the best thickness, purity, and continuity. The Upper Mercer limestone possesses good continuity but it is generally highly cherty and siliceous whereas the Vanport lacks both purity and persistence. The Poverty Run and Boggs limestones are each represented by only a few inches of impure limestone exposed at a few localities in Jefferson Township and merit no further discussion here. Small quarries have operated in the Putnam Hill and Lower Mercer limestones in Pike, Perry, Newcastle, Monroe, and White Eyes townships.

In drilling wells for oil and gas in Coshocton County no limestones are encountered below drainage until the Middle Devonian beds are reached at depths below sea level ranging from about 900 feet in the northwest corner to approximately 2,100 feet in the southeast part of the county.

Lower Mercer Limestone

The Lower Mercer limestone outcrops in every township in Coshocton County but due to the structural conditions it occurs high on the hillsides in the western part and near drainage level along the larger valleys at the eastern edge of the area. The thickness of the Lower Mercer limestone varies in this county from a few inches to 5 feet 6 inches but the average of 47 measurements is about 2 feet 3 inches. It is persistent on the outcrop with few cut-outs and depositional omissions. It is known to occur in good development along Evans Creek in Adams Township, in the valley of White Eyes Creek in White Eyes Township, in Mill Creek and eastern Clark townships, along Simmons Run in Jackson Township, near Moscow in Virginia Township, and at various localities in Bedford Township. The Lower Mercer has been utilized in a small way for agricultural purposes in this county.

The Lower Mercer limestone outcrops at an elevation of about 890 feet along a small valley in the northeastern part of White Eyes Township about one mile northwest of Woods School. Here the limestone occurs in exceptional development for this county. A description of the rock exposures along the valley is given below:

		Ft.	In.
Limestone, Putnam Hill		1	6
Shale, dark, carbonaceous		-	6
Shale, black, and shaly coal	Brookville	-	6
Coal	Brookville	1	4
Parting, clay shale	Brookville	1	0
Coal	Brookville	2	6
Covered interval		37	0
Limestone, black, flinty	Upper Mercer	1	8
Limestone, black, dense-textured, one layer	Upper Mercer	1	8
Shale and covered	Upper Mercer	5	0
Limestone, black, dense-textured, flinty	Upper Mercer	4	0
Shale, dark, arenaceous		-	8
Shale, bony, Bedford coal horizon		-	6
Clay, gray, arenaceous		5	0
Shale, arenaceous, and covered		20	0
Limestone, dark bluish gray, dense, one layer	Lower Mercer	1	0
Limestone, dark bluish gray, dense, one layer	Lower Mercer	0	9
Limestone, dark bluish gray, dense, one layer	Lower Mercer	-	9
Limestone, dark bluish gray, dense, one layer	Lower Mercer	2	0
Limestone, dark bluish gray, hard, dense, one layer	Lower Mercer	1	0

The Lower Mercer limestone at this locality, having a total thickness of 5 feet 6 inches, was sampled for chemical analysis by R. E. Lamborn on April 30, 1941.

Sample No. 321

Chemical analysis of Lower Mercer limestone from outcrop one mile northwest of Woods School, White Eyes Township, Coshocton County, Downs Schaaf, analyst.

	Per cent
Silica, SiO_2	4.59
Alumina, Al_2O_3	1.25
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.86
Iron disulphide, FeS_2	0.16
Magnesium oxide, MgO	1.10
Calcium oxide, CaO	49.92
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.05
Water, hydroscopic, H_2O-	0.19
Water, combined, H_2O+	0.35
Carbon dioxide, CO_2	40.61
Titanium dioxide, TiO_2	0.05
Phosphorus pentoxide, P_2O_5	0.28
Sulphur trioxide, SO_3	0.18
Manganous oxide, MnO	0.14
Carbon, organic, C	0.27
Hydrogen, organic, H	0.02
Total	100.06

The per cent of each of the mineral compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.67
Silicates $Al_2O_3.2SiO_2.2H_2O$	2.50
Silica, SiO_2	3.12
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.39
Iron disulphide, FeS_2	0.16
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO.P_2O_5$	0.61
Calcium sulphate, $CaO.SO_3$	0.30
Calcium carbonate, $CaO.CO_2$	88.28
Magnesium carbonate, $MgO.CO_2$	2.30
Manganese carbonate, $MnO.CO_2$	0.23
Water, hydroscopic, H_2O-	0.19
Organic matter	0.29
Unbalanced components (excess CO_2, H_2O)	-0.05
Total	100.06

The Lower Mercer limestone has been quarried to a small extent on the Boyd property in the west central part of Section 6, White Eyes Township. The stone was ground to the necessary fineness and utilized in the carbonate form for agricultural purposes. A description of the rock outcrops is given below:

	Ft.	In.
Shale, soft, carbonaceous	2	6
Limestone, dark bluish gray, dense texture, fossiliferous, one bed, Lower Mercer	3	2

Coal, shaly, and black shale, Middle Mercer	-	6
Clay, dark, plastic	1	0

A sample of the Lower Mercer limestone from the Boyd quarry was collected by the writer on May 23, 1941, and was submitted for analysis.

Sample No. 340

Chemical analysis of Lower Mercer limestone from quarry on Boyd property, Section 6, White Eyes Township, Coshocton County, Downs Schaaf, analyst.

	Per cent
Silica, SiO_2	3.11
Alumina, Al_2O_3	1.40
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	1.55
Iron disulphide, FeS_2	0.23
Magnesium oxide, MgO	1.14
Calcium oxide, CaO	49.95
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.10
Water, hydroscopic, H_2O-	0.24
Water, combined, H_2O+	0.40
Carbon dioxide, CO_2	41.36
Titanium dioxide, TiO_2	0.07
Phosphorus pentoxide, P_2O_5	0.07
Sulphur trioxide, SO_3	0.09
Manganous oxide, MnO	0.19
Carbon, organic, C	0.07
Hydrogen, organic, H	--
Total	100.01

The per cent of each of the compounds probably present in Sample No. 340 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.09
Silicates $Al_2O_3.2SiO_2.H_2O$	2.47
Silica, SiO_2	1.46
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	2.50
Iron disulphide, FeS_2	0.23
Titanium dioxide, TiO_2	0.07
Calcium phosphate, $3CaO.P_2O_5$	0.15
Calcium sulphate, $CaO.SO_3$	0.16
Calcium carbonate, $CaO.CO_2$	88.89
Magnesium carbonate, $MgO.CO_2$	2.38
Manganese carbonate, $MnO.CO_2$	0.31
Water, hydroscopic, H_2O-	0.24
Organic matter	0.07
Unbalanced components (excess CO_2, H_2O)	-0.03
Total	100.01

The Lower Mercer limestone in unusually thick development outcrops at an elevation of about 940 feet along a deep ravine in the north central part of Section 22, Clark Township, about one mile southeast of Helmick. The exposures at this locality are described as follows:

		Ft.	In.
Limestone, bluish gray, Putnam Hill		-	6
Clay and covered		5	0
Shale and covered		38	6
Limestone and black flint, Upper Mercer		2	6
Covered interval		23	2
Limestone, bluish gray, hard, fossiliferous	Lower Mercer	-	7
Limestone, bluish gray, fossiliferous, shaly where weathered	Lower Mercer	2	6
Limestone, bluish gray, hard, fossiliferous	Lower Mercer	1	2
Clay shale, dark bluish gray		-	8

Lower Mercer limestone having a thickness of 4 feet 3 inches at this locality was sampled for chemical analysis on September 8, 1944, by R. E. Lamborn.

Sample No. 439

Chemical analysis of Lower Mercer limestone from outcrop, north central Section 22, Clark Township, Coshocton County, E. Chadbourn, analyst.

	Per cent
Silica, SiO_2	2.38
Alumina, Al_2O_3	0.54
Ferric oxide, Fe_2O_3	0.38
Ferrous oxide, FeO	0.94
Iron disulphide, FeS_2	0.24
Magnesium oxide, MgO	0.87
Calcium oxide, CaO	51.44
Sodium oxide, Na_2O	0.07
Potassium oxide, K_2O	0.12
Water, hydroscopic, H_2O-	0.08
Water, combined, H_2O+	0.76
Carbon dioxide, CO_2	41.28
Titanium dioxide, TiO_2	0.02
Phosphorus pentoxide, P_2O_5	0.20
Sulphur trioxide, SO_3	0.12
Manganous oxide, MnO	0.12
Total	99.56

The per cent of each of the mineral components present in Sample No. 439 as determined by calculation (Lamborn) from the chemical analysis is as follows:

Silica and hydrated aluminum silicates of sodium and potassium	3.81
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.44
Ferrous carbonate, $FeO.CO_2$	1.52
Iron disulphide, FeS_2	0.24
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO.P_2O_5$	0.44
Calcium sulphate, $CaO.SO_3$	0.20
Calcium carbonate, $CaO.CO_2$	91.24
Magnesium carbonate, $MgO.CO_2$	1.82
Manganese carbonate, $MnO.CO_2$	0.19
Water, hydroscopic, H_2O-	0.08

Unbalanced components (excess CO_2)	-0.44
Total	99.56

The Lower Mercer is well developed as a limestone member along the valley of Simmons Run in the western part of Jackson Township. Here it is heavy bedded, hard, and weather resistant. Outcrops occur at a number of places at an elevation of about 900 feet. A description of the beds exposed along the road in the northeast quarter of Section 15, Jackson Township, is given in the following section:

		Ft.	In.
Limestone, black, flinty, Upper Mercer		2	2
Coal, shaly, and black shale, Bedford		1	3
Clay, gray and covered		4	4
Shale, gray, arenaceous		13	6
Ore, carbonate, nodular		-	3
Limestone, dark bluish gray, fossiliferous	Lower Mercer	-	3
Limestone, one layer, dark bluish gray, fossiliferous	Lower Mercer	3	0
Limestone, dark bluish gray, fossiliferous, one layer	Lower Mercer	-	6
Shale, black, carbonaceous, Middle Mercer coal horizon		-	6
Clay, bluish gray, arenaceous		9	2

The Lower Mercer limestone at this locality, having a total thickness on the outcrop of 3 feet 9 inches, was sampled by R. E. Lamborn for chemical analysis on June 10, 1941.

Sample No. 343

Chemical analysis of Lower Mercer limestone from outcrop in the northeast quarter of Section 15, Jackson Township, Coshocton County, Downs Schaaf, analyst.

	Per cent
Silica, SiO_2	2.68
Alumina, Al_2O_3	1.01
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	1.05
Iron disulphide, FeS_2	0.19
Magnesium oxide, MgO	0.92
Calcium oxide, CaO	51.31
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	0.01
Water, hydroscopic, H_2O-	0.18
Water, combined, H_2O+	0.29
Carbon dioxide, CO_2	41.80
Titanium dioxide, TiO_2	0.05
Phosphorus pentoxide, P_2O_5	0.15
Sulphur trioxide, SO_3	0.06
Manganous oxide, MnO	0.16
Carbon, organic, C	0.12

Hydrogen, organic, H	0.01
Total	100.02

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2 . 3Al_2O_3 . 6SiO_2 . 2H_2O$	0.08
Silicates $Al_2O_3 . 2SiO_2 . 2H_2O$	2.47
Silica, SiO_2	1.49
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	1.69
Iron disulphide, FeS_2	0.19
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO.P_2O_5$	0.33
Calcium sulphate, $CaO.SO_3$	0.10
Calcium carbonate, $CaO.CO_2$	91.19
Magnesium carbonate, $MgO.CO_2$	1.92
Manganese carbonate, $MnO.CO_2$	0.26
Water, hydroscopic, H_2O-	0.18
Organic matter	0.13
Unbalanced components (excess CO_2, H_2O)	-0.10
Total	100.02

In Virginia Township the Lower Mercer limestone is well exposed at a number of localities along Moscow Fork and along Mill Fork southwest of central Section 8. One of the thickest exposures in this area occurs along a small ravine on the Ralph Foster property in the central part of Section 15, where the measurement is 3 feet 7 inches. A description of the exposures at this locality follows:

		Ft.	In.
Limestone, light bluish gray to gray black, dense, fossiliferous	Lower Mercer	1	3
Limestone, dark bluish gray, somewhat shaly	Lower Mercer	1	0
Limestone, bluish gray, dense, fossiliferous, slightly shaly	Lower Mercer	1	4
Shale, bluish gray		3	0
Bottom of exposure.			

On July 28, 1943, the Lower Mercer limestone at this exposure was sampled by R. E. Lamborn for chemical analysis.

Sample No. 412

Chemical analysis of Lower Mercer limestone from outcrop, central Section 15, Virginia Township, Coshocton County, E. Chadbourn, analyst.

	Per cent
Silica, SiO_2	3.28
Alumina, Al_2O_3	1.09
Ferric oxide, Fe_2O_3	0.21
Ferrous oxide, FeO	0.85
Iron disulphide, FeS_2	0.32
Magnesium oxide, MgO	0.85
Calcium oxide, CaO	50.95
Sodium oxide, Na_2O	0.08

Potassium oxide, K_2O	0.22
Water, hydroscopic, H_2O-	0.13
Water, combined, H_2O+	0.57
Carbon dioxide, CO_2	40.80
Titanium dioxide, TiO_2	0.05
Phosphorus pentoxide, P_2O_5	0.19
Sulphur trioxide, SO_3	0.12
Manganous oxide, MnO	0.12
Total	99.83

The per cent of each of the mineral components in the sample as calculated (Lamborn) from the chemical analysis is as follows:

Silica and hydrated aluminum silicates of sodium and potassium	5.20
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.25
Ferrous carbonate, FeO, CO_2	1.37
Iron disulphide, FeS_2	0.32
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO. P_2O_5$	0.41
Calcium sulphate, $CaO. SO_3$	0.20
Calcium carbonate, $CaO. CO_2$	90.39
Magnesium carbonate, $MgO. CO_2$	1.78
Manganese carbonate, $MnO. CO_2$	0.19
Water, hydroscopic, H_2O-	0.13
Unbalanced components (excess CO_2)	-0.46
Total	99.83

Upper Mercer Limestone

Outcrops of the Upper Mercer limestone horizon occur in every township in Coshocton County but the limestone is generally thin and is everywhere highly siliceous and impure in composition. Its stratigraphic position is on an average about 29 feet above the Lower Mercer limestone previously described. The Upper Mercer is generally a hard, black, dense-textured, fossiliferous limestone occurring either as a single bed or layer or as two or more layers separated by bedding planes only. Nodules of black flint are of common occurrence in the limestone and not infrequently the top of the member is a solid bed of black flint. In parts of Adams and Keene townships the Upper Mercer consists of two beds of hard, black, siliceous limestone separated by a thin bed of dark arenaceous shale which varies from 5 feet to 6 feet in thickness. Locally a thin bed of iron ore occurs immediately overlying the limestone. The thickness of the Upper Mercer in Coshocton County varies from a few inches to more than 15 feet, but the average of 47 measurements taken in the field is about 2 feet. A thickness of 3 feet or more of this impure limestone is of common occurrence in Adams and Keene townships. An exceptional thickness of the Upper Mercer member occurs near the head of Flint Run in the southern part of Jefferson Township. Here the following measurements were secured by Ralph Meyers in 1927.

		Ft.	In.
Limestone, Putnam Hill		3	4
Coal, Brookville		1	7
Clay, white, plastic		2	6
Covered interval		9	6
Flint, blue black, weathers a chocolate brown	Upper Mercer	3	9

Limestone, dark blue, arenaceous, fossiliferous	Upper Mercer (cont.)	9	3
Flint, black, fossiliferous	Upper Mercer (cont.)	1	11
Coal, Bedford		2	6

The Upper Mercer in Coshocton County is generally too siliceous to be attractive as a source for limestone where a high calcium carbonate content is an essential quality.

Putnam Hill Limestone

The Putnam Hill limestone is, in general, typical in its lithologic characteristics and mode of occurrence in Coshocton County as it is with few exceptions a gray to bluish gray, heavy-bedded fossiliferous limestone of fair purity. Nodular flint embedded in the limestone is not a conspicuous feature of the Putnam Hill in this area. The thickness of the Putnam Hill on the outcrop in Coshocton County varies in general from a few inches to about 7 feet but in a few small areas it exceeds 10 feet. The average of 46 measurements on the outcrop is about 2 feet. The position of the member in the stratigraphic column is on an average about 72 feet above the Lower Mercer limestone, 43 feet above the Upper Mercer limestone, and about 84 feet below the Middle Kittanning coal. Although the Putnam Hill occurs above drainage in the eastern half of the county its field of greatest thickness and highest purity is found in Monroe, Jefferson, Bedford, Washington, Pike, Perry, Newcastle, and eastern Virginia townships. Here it has been quarried at a number of localities along the outcrop and utilized for various economic purposes.

The Putnam Hill limestone has been quarried on a small scale along the outcrop on the N. J. Markley property in the southwest quarter of Section 19, Monroe Township. The stone is crushed on the premises and the powdered stone is used locally for agricultural limestone. A description of the rock exposures at this locality is given below:

		Ft.	In.
Soil and slump		5	0
Limestone, dark bluish gray, generally dense-textured, fossiliferous, one bed	Putnam Hill	4	0
Limestone, light bluish to brownish gray, fossiliferous, one bed	Putnam Hill	-	6
Coal, exposed, Brookville or No. 4		1	6
Covered interval		26	0
Limestone, black, flinty, Upper Mercer		1	0
Coal, shaly, and black shale	Bedford	-	4
Coal, bony, cannel nature	Bedford	1	0
Clay, gray, arenaceous		1	8
Sandstone, shaly, and sandy shale		2	0
Shale, dark bluish		-	6
Shale, bony		-	1
Clay, gray		2	0
Shale and covered		2	9
Covered interval		10	0
Limestone, dark bluish gray, heavy-bedded, Lower Mercer		4	0

The Putnam Hill limestone on the Markley property was sampled by R. E. Lamborn for chemical analysis on June 10, 1942.

Sample No. 342

Chemical analysis of Putnam Hill limestone from quarry on N. J. Markley property, Section 19, Monroe Township, Coshocton County, Downs Schaaf, analyst.

	Per cent
Silica, SiO_2	2.21
Alumina, Al_2O_3	0.70
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	0.65
Iron disulphide, FeS_2	0.12
Magnesium oxide, MgO	0.90
Calcium oxide, CaO	52.30
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	0.02
Water, hydroscopic, H_2O-	0.14
Water, combined, H_2O+	0.18
Carbon dioxide, CO_2	42.34
Titanium dioxide, TiO_2	0.06
Phosphorus pentoxide, P_2O_5	0.12
Sulphur trioxide, SO_3	0.03
Manganous oxide, MnO	0.14
Carbon, organic, C	0.09
Hydrogen, organic, H	--
Total	100.03

The per cent of each of the compounds probably present in Sample No. 342 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.17
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.61
Silica, SiO_2	1.38
Hydrated ferric oxide, $2Fe_2O_3.2H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	1.05
Iron disulphide, FeS_2	0.12
Titanium dioxide, TiO_2	0.06
Calcium phosphate, $3CaO.P_2O_5$	0.26
Calcium sulphate, $CaO.SO_3$	0.05
Calcium carbonate, $CaO.CO_2$	93.05
Magnesium carbonate, $MgO.CO_2$	1.88
Manganese carbonate, $MnO.CO_2$	0.23
Water, hydroscopic, H_2O-	0.14
Organic matter	0.09
Unbalanced components (excess CO_2, H_2O)	-0.10
Total	100.03

South of Monroe Township the Putnam Hill occurs in good development through Jefferson and Bedford townships where its average thickness is near 4 feet 6 inches. It likewise occurs in good thickness and purity in Perry Township. An exceptional development of Putnam Hill limestone outcrops on the W. R. Speckman property near the crest of the high knob in the northwest quarter of Section 4, Perry Township. Here the stone has been quarried for a number of years for road mettle and for agricultural use. An examination of the face of the stone yielded the following description:

			Ft.	In.
Limestone, bluish gray, weathers into nodular layers an inch or so in thickness	Putnam Hill		5	0
Limestone, bluish gray, thin-bedded			2	0
Limestone, light bluish to brownish gray, one bed			1	3
Limestone, bluish to light brownish gray, massive, one bed			3	0

A sample of the 13 feet 2 inches of limestone exposed in this quarry was secured by R. E. Lamborn for chemical analysis on June 9, 1941.

Sample No. 341

Chemical analysis of Putnam Hill limestone from quarry on the W. R. Speckman property, Section 4, Perry Township, Coshocton County, Downs Schaaf, analyst.

	Per cent
Silica, SiO_2	2.61
Alumina, Al_2O_3	0.55
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.64
Iron disulphide, FeS_2	0.06
Magnesium oxide, MgO	0.75
Calcium oxide, CaO	52.50
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	0.01
Water, hydroscopic, H_2O-	0.14
Water, combined, H_2O+	0.15
Carbon dioxide, CO_2	42.33
Titanium dioxide, TiO_2	0.06
Phosphorus pentoxide, P_2O_5	0.10
Sulphur trioxide, SO_3	0.01
Manganous oxide, MnO	0.07
Carbon, organic, C	0.07
Hydrogen, organic, H	--
Total	100.07

The per cent of each of the mineral compounds probably present in the sample has been computed (Lamborn) from the chemical analysis:

Silicates $(Na, K)_2 . 3Al_2O_3 . 6SiO_2 . 2H_2O$	.08
Silicates $Al_2O_3 . 2SiO_2 . 2H_2O$	1.31
Silica, SiO_2	1.96
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.02
Ferrous carbonate, $FeO . CO_2$	1.03
Iron disulphide, FeS_2	0.06
Titanium dioxide, TiO_2	0.06
Calcium phosphate, $3CaO . P_2O_5$	0.22
Calcium sulphate, $CaO . SO_3$	0.02

Calcium carbonate, $CaO.CO_2$	93.48
Magnesium carbonate, $MgO.CO_2$	1.57
Manganese carbonate, $MnO.CO_2$	0.11
Water, hydroscopic, H_2O-	0.14
Organic matter	0.07
Unbalanced components (excess CO_2, H_2O)	-0.06
Total	100.07

The Putnam Hill limestone was formerly quarried on the Beal farm in the southeast quarter of Section 13, Newcastle Township, and the stone was pulverized and marketed as agricultural lime. Good exposures of the limestone occur in the cut along the highway just south of the Beal home where the following measurements were secured.

		Ft.	In.
Limestone, bluish to light brownish gray, fossiliferous, appears shaly on weathering	Putnam Hill	6	2
Limestone, bluish to light brownish gray, dense, hard, compact	Putnam Hill	2	2

The limestone described above having a total thickness of 8 feet 4 inches was sampled on July 26, 1943, by R. E. Lamborn for chemical analysis.

Sample No. 402

Chemical analysis of Putnam Hill limestone from outcrop, Section 13, Newcastle Township, Coshocton County, E. Chadbourn, analyst.

	Per cent
Silica, SiO_2	2.71
Alumina, Al_2O_3	1.00
Ferric oxide, Fe_2O_3	0.29
Ferrous oxide, FeO	0.68
Iron disulphide, FeS_2	0.24
Magnesium oxide, MgO	0.76
Calcium oxide, CaO	51.68
Sodium oxide, Na_2O	0.04
Potassium oxide, K_2O	0.16
Water, hydroscopic, H_2O-	0.05
Water, combined, H_2O+	0.45
Carbon dioxide, CO_2	41.66
Titanium dioxide, TiO_2	0.03
Phosphorus pentoxide, P_2O_5	0.06
Sulphur trioxide, SO_3	0.12
Manganous oxide, MnO	0.07
Total	100.00

The per cent of each of the probable mineral constituents as computed (Lamborn) from the chemical analysis is given below.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.85
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.72
Silica, SiO_2	1.53
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.34

Ferrous carbonate, $FeO.CO_2$	1.10
Iron disulphide, FeS_2	0.24
Titanium dioxide, TiO_2	0.03
Calcium phosphate, $3CaO.P_2O_5$	0.13
Calcium sulphate, $CaO.SO_3$	0.20
Calcium carbonate, $CaO.CO_2$	91.96
Magnesium carbonate, $MgO.CO_2$	1.59
Manganese carbonate, $MnO.CO_2$	0.11
Water, hydroscopic, H_2O-	0.05
Unbalanced components (deficiency CO_2, H_2O)	+0.15
Total	100.00

The Putnam Hill is conspicuous on the outcrop near the crest of Virginia Ridge in eastern Pike Township and western Washington Township. The usual thickness of the limestone is about 4 feet and the quality is excellent. The stone has been quarried, crushed, and marketed for agricultural use near Clark School in the southwest quarter of Section 10, Pike Township. The following measurements were secured at this locality.

	Ft.	In.
Limestone, hard, bluish gray, dense to finely crystalline in texture, Putnam Hill, elevation 1,060 feet	5	0
Covered interval	85	0
Limestone, dark bluish gray, fossiliferous, Lower Mercer	2	0

On May 1, 1941, the stone at this quarry was sampled by R. E. Lamborn for chemical analysis.

Sample No. 322

Chemical analysis of Putnam Hill limestone from quarry located in Section 10, Pike Township, Coshocton County, Downs Schaaf, analyst.

	Per cent
Silica, SiO_2	1.95
Alumina, Al_2O_3	0.44
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.50
Iron disulphide, FeS_2	0.15
Magnesium oxide, MgO	0.86
Calcium oxide, CaO	52.82
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.01
Potassium oxide, K_2O	0.02
Water, hydroscopic, H_2O-	0.11
Water, combined, H_2O+	0.11
Carbon dioxide, CO_2	42.61
Titanium dioxide, TiO_2	0.03
Phosphorus pentoxide, P_2O_5	0.10
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.10
Carbon, organic, C	0.15
Hydrogen, organic, H	0.01
Total	100.03

The per cent of each of the mineral compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.29
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.82
Silica, SiO_2	1.43
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	0.81
Iron disulphide, FeS_2	0.15
Titanium dioxide, TiO_2	0.03
Calcium phosphate, $3CaO.P_2O_5$	0.22
Calcium sulphate, $CaO.SO_3$	0.07
Calcium carbonate, $CaO.CO_2$	94.01
Magnesium carbonate, $MgO.CO_2$	1.80
Manganese carbonate, $MnO.CO_2$	0.16
Water, hydroscopic, H_2O-	0.11
Organic matter	0.16
Unbalanced components (excess CO_2, H_2O)	-0.05
Total	100.03

Vanport Limestone

The only member occurring in Coshocton County above the Putnam Hill worthy of any consideration as a source of limestone is the Vanport. The position of this member is on an average about 30 feet above the Putnam Hill limestone, 24 feet below the Lower Kittanning coal, and about 60 feet below the Middle Kittanning coal. In general the Vanport is very patchy in distribution in Coshocton County and where it does occur in good thickness it is usually highly siliceous and impure in composition. In Adams, Lafayette, and Tuscarawas townships, where small local deposits of this member occur, the Vanport is represented by a bluish gray limestone a foot or so in thickness or by white milky or yellowish brown chert. The thickest known deposits of this member are found in Bedford Township. Here it consists of shaly ferruginous limestone and flint aggregating in places as much as 9 feet in thickness. The Vanport has not been utilized to any extent in Coshocton County.

CUYAHOGA COUNTY

General Considerations

The bedrocks which crop out in Cuyahoga County consist entirely of sandstone, shale, and conglomerate. The various series represented include the Chagrin and Cleveland shales of Upper Devonian age, the Bedford, Berea, Sunbury, and Cuyahoga formations of the Mississippian system, and the Sharon conglomerate of the Pennsylvanian system. Outcrops of the Chagrin and Cleveland shales are confined to the lower slopes bordering Lake Erie whereas the distribution of the Sharon is limited to a few hilltops in the southern and southeastern parts of the county. The total thickness of the series exposed over the 457 square miles comprising the area of this county is approximately 700 feet. No well defined limestones occur in the section exposed. Wells drilled for oil and gas in different parts of the county reach the Middle Devonian limestones and dolomites at depths below sea level varying from about 300 feet in the northwest corner to approximately 1,000 feet in Solon Township in the southeast corner of the county.

FAIRFIELD COUNTY

General Considerations

No actual or potential resources of limestone occur in the bedrock series cropping out in Fairfield County. The series which reaches the surface in this area consists almost entirely of sandstone, shale, and conglomerate. The succession represented includes the Bedford, Berea, Sunbury, Cuyahoga, and Logan formations of the Mississippian system and the lower 150 feet of the Pottsville series of the Pennsylvanian system. The regional inclination of the beds in Fairfield County is in a direction a little south of east. The lowest formation of the succession, the Bedford shale, is due therefore close above drainage in the northwestern part of Violet Township whereas the distribution of the youngest or Pottsville beds is confined to the hilltops in eastern Richland and Berne townships and eastern and southern Rush Creek Township. The Maxville limestone quarried at a few localities in Perry and Muskingum counties is wanting on the outcrop in Fairfield County. The total thickness of the sedimentary series above drainage in this county is in excess of 700 feet. Below drainage shales extend downward for several hundreds of feet to the top of the Middle Devonian limestone which is reached in wells at levels ranging from 300 feet above tide in northwestern Violet Township to 900 feet below tide in southeastern Rush Creek Township.

GALLIA COUNTY

General Considerations

The bedrocks which reach the surface in Gallia County comprise that part of the Pennsylvanian system which occurs above the base of the Allegheny series. The total vertical thickness of the series represented in outcrops is not far from 875 feet. Outcrops of the Allegheny series occur over narrow elongated areas along the valleys of Symmes Creek and Raccoon Creek and their chief tributaries in the western third of the county. Beds of Conemaugh age underlie the uplands throughout the central part, whereas strata of the Monongahela series comprise the hills in the eastern part and occur in somewhat greater thickness and wider extent in the southeastern corner of the area. A generalized section of the strata exposed in Gallia County, showing the members represented insofar as the sequence has been determined by the field investigations of Condit [1] and Stout, [2] is given below:

Generalized Section of Bedrocks Outcropping in Gallia County

	Ft.	In.
Pennsylvanian system		
Monongahela series		
Sandstone and shale with one or more coal beds. Details of succession lacking. Approximate thickness	300	0
Conemaugh series		
Clay	5	0
Shale, sandy	28	0
Sandstone, massive, represented by sandy shale in parts of county, Connellsville	35	0
Shale, sandy, interbedded with red clay having nodules of limestone and hematite	65	0

[1] *Condit, D. D., Conemaugh Formation in Ohio: Geol. Survey Ohio Bull. 17, pp. 77-78, 1912.*

[2] *Stout, Wilbur, Geology of Southern Ohio: Geol. Survey Ohio Bull. 20, pp. 604-605, 1916; Geology of Vinton County: Geol. Survey Ohio Bull. 31, p. 110, 1927.*

Sandstone, massive, prominent in southern part, missing to northward, Morgantown		30	0
Limestone, locally present, Ames		1	0
Shale and red clay with nodular limestones		40	0
Limestone, ferruginous, fossiliferous, local, Portersville		-	8
Coal, thin, local, Anderson		-	-
Shale		38	0
Limestone, dark gray, fossiliferous, with flinty layers, Cambridge		3	0
Coal, thin, Wilgus		1	0
Shale and sandstone		26	0
Limestone	Brush Creek	2	0
Shale	Brush Creek	24	0
Limestone	Brush Creek	2	0
Shale		10	0
Coal, thin, Mason		1	0
Shale and sandstone		28	0
Coal, Mahoning		1	0
Clay shale		2	0
Shale		10	0
Sandstone, Mahoning		30	0
Allegheny series			
Coal	Upper Freeport or No. 7	1	3
Clay shale	Upper Freeport or No. 7	-	5
Coal	Upper Freeport or No. 7	-	7
Clay	Upper Freeport or No. 7	-	3
Coal	Upper Freeport or No. 7	3	1
Clay		3	0
Sandstone and shale		50	0
Coal, Lower Freeport		1	4
Clay		3	0
Sandstone and shale		50	0
Coal, Lower Freeport		1	4
Sandstone and shale		24	0
Coal	Middle Kittanning or No. 6	1	0
Clay shale	Middle Kittanning or No. 6	-	5
Coal	Middle Kittanning or No. 6	2	1
Clay		3	0
Sandstone and shale		35	0
Coal, Lower Kittanning or No. 5		1	8
Clay		7	0
Clay, sandstone, and shale		16	0
Ore, Ferriferous		-	4
Limestone, Vanport		6	0
Coal	Clarion or No. 4a	1	2
Clay	Clarion or No. 4a	-	7
Coal	Clarion or No. 4a	1	3
Clay, impure	Clarion or No. 4a	-	1
Coal	Clarion or No. 4a	-	11
Clay		2	0
Sandstone, Clarion		31	0
Coal, wanting, Winters		-	-
Flint and ore, Zaleski		1	0
Shale, with ore layers or sandstones		9	0
Shale, fossiliferous		12	0
Coal, Brookville or No. 4		1	4

Gallia County is not especially outstanding in the number of limestones outcropping within its borders or in the magnitude of their development and purity of their character. Of the six limestone members reaching the surface two are found in the lower part of the Allegheny series and four occur in the Conemaugh. Of these the Vanport, Brush Creek, and Cambridge members are, generally speaking, the most important and they have received the most attention as sources for limestone. Quarries have operated in these members at various times along the outcrop in Greenfield, Morgan, Springfield, Perry, and Walnut townships for the production of agricultural lime and for stone for highway construction and repair.

Underlying the lowest beds exposed in Gallia County to depths penetrated in drilling for oil and gas the various rock series in descending order include the sandstones and shales with possible thin coal and clay beds belonging to the lower part of Pennsylvanian system; sandstone and shale with erosional remnants of limestone (Maxville) of the Mississippian system; a thick series of shales representing the top part of the Devonian system; a thick series of limestones and dolomites of the lower part of the Devonian and the upper part of the Silurian systems; and a series of sandstones and shales belonging to the lower part of the Silurian system. Well data indicate that the Mississippian limestone is only locally present in Gallia County whereas the deeper limestones and dolomites of Devonian and Silurian ages are widespread. In wells drilled to the Clinton sand in this county, the Devonian limestone is first encountered at depths below sea level ranging from about 1,250 feet in northwestern Greenfield Township to an estimated 2,600 feet in southeastern Ohio Township.

Maxville Limestone

Of those limestones occurring below drainage and at reasonable depths from the surface in this county the Maxville merits chief attention. Records of wells drilled to the Berea sand for oil and gas indicate that the Maxville is present in the eastern part of the county north of Gallipolis over an elongated area embracing much of the eastern two-thirds of Addison Township and the southeastern part of Cheshire Township. Future drilling may extend the boundaries of this area or reveal new areas of occurrence in this county not now known. Where present in Cheshire and Addison townships the thickness of the Maxville limestone, according to well records, varies from 50 feet to 185 feet with many records showing 100 feet or more of this limestone. The depth below the surface varies over the field from a minimum of 750 feet on the valley bottoms to a maximum of about 1,150 feet on the hilltops.[1]

During the latter part of 1946 Jones and Laughlin Ore Company drilled two core holes in Addison Township to explore the economic possibilities of Maxville limestone in that area. Test hole No. 2 was drilled to a depth of 961 feet on the Arrowood property near Addison in the southwest part of the northeast quarter of Section 15. The second test, No 10-A, was sunk on the Bradbury property some two miles southwest of Addison. The hole is located along a small tributary to George Creek in the southeast quarter of Section 20. In both tests the drill penetrated Maxville limestone in excess of 100 feet in thickness. By courtesy of L. P. Barrett of Jones and Laughlin Ore Company the cores are now in files of the Geological Survey. They were examined by G. W. White in June 1947. White's description of core from Hole No. 2 with his identification of geologic horizons penetrated is as follows:

[1] *Lamborn, Raymond E., Recent information on the Maxville Limestone: Geol. Survey Ohio Inf. Circ. No. 3, p. 12, 1945.*

	Thickness Ft.	In.	Depth Ft.	In.
No core	28	0	28	0
Shale, red, calcareous, and clay shale, greenish gray, calcareous	1	6	29	6
Limestone, gray green, fine-grained, cemented breccia, thin calcite veinlets, Ames	2	6	32	0
Sandstone, gray green, fine-grained, calcareous	2	6	34	6
Sandstone, gray green, non-calcareous, very fine-grained; in part siltstone	5	0	39	6
Sandstone, light gray, medium-grained; in part calcareous, several thin limestone fragments; some micaceous laminations	11	6	51	0
Shale, dark greenish gray, fine-grained	11	6	62	6
Clay shale, alternating green and gray	3	0	65	6
Clay shale, gray; lower half calcareous, with small limestone nodules	1	8	67	2
Clay shale, red, very calcareous, with small limestone nodules. One foot gray zone at 82 feet. Bottom 2 feet non-calcareous	23	4	90	6
Shale, greenish gray; in part silty	5	6	96	0
Shale, maroon and light gray; bottom part calcareous	10	6	106	6
Sandstone, greenish gray, calcareous, very fine-grained. At 109-114 feet coarser, lighter, and almost sandy limestones	7	6	114	0
Shale, greenish gray, grading from silty above the clayey below; contains irregular masses of limestone 1 1/2 inches in size	14	0	128	0
Clay shale, red	2	7	130	7
Clay shale, grayish green, calcareous	1	0	131	7
Limestone, light buff gray, very fine-grained to dense, sparingly fossiliferous; thin shale films on bedding planes which have begun to form stylolites, Cambridge	3	8	135	3
Shale, dark brownish green, fine-grained; calcareous in lower part	6	1	141	4
Siltstone, grayish green; almost fine sandstone	2	0	143	4
Shale, grayish green; silty at top, finer below	4	0	147	4
Sandstone, fine to medium-grained, very calcareous; almost limestone	5	6	152	10
Siltstone, greenish gray, laminated	12	11	165	9
Limestone, buff gray, fine-grained to dense, in irregular beds 2 to 6 inches separated by dark green shale; in part rolled fragments; bottom 3 inches very sandy, almost cal-				

careous sandstone; marine fossils present. Brush Creek	2	8	168	5
Shale, brownish green, fine-grained	2	7	171	0
Clay shale, maroon and green mottled	7	0	178	0
Clay shale, with carbonaceous streaks	-	2	178	2
Shale, gray green, fine-grained, laminated; a few thin sandy calcareous layers; finer-grained toward base	20	5	198	7
Clay shale, dark gray, with carbonaceous streaks	-	10	199	5
Sandstone, white, medium-grained; coarser downward; very calcareous from 211-215 feet and 224-225 feet	27	2	226	7
Coal; lower 1 inch carbonaceous shale; several pyrite layers of 1/8 inch or more, Mahoning	-	11	227	6
Clay, gray, plastic, Thornton	1	6	229	0
Clay, dark gray, with many limestone nodules in upper 2 feet	4	6	233	6
Clay shale, red; 1 foot gray layer at 246	18	6	252	0
Siltstone, grayish green, massive	3	6	255	6
Sandstone, white, medium to coarse, feldspathic	10	6	266	0
Clay, buff, plastic	3	0	269	0
Shale and siltstone, greenish gray; 6 inches of calcareous sandstone at 275 feet	8	6	277	6
Clay shale, dark gray	10	2	287	8
Limestone, tan, dense, ferruginous	-	4	288	0
Shale, dark gray, fine-grained; in part clay shale; in part calcareous with thin layers and masses of limestone	25	6	313	6
Siderite, tan, impure	-	6	314	0
Shale, dark gray, silty, laminated	2	0	316	0
Sandstone, white, medium-grained, micaceous and calcareous, cross-bedded	3	0	319	0
Shale, dark gray, silty, with calcareous sandstone streaks	1	10	320	10
Clay, dark gray, in part slightly calcareous	3	2	324	0
Shale, dark gray, fine-grained	3	2	327	2
Shale, black, carbonaceous	-	1	327	3
Sandstone, white, medium to coarse, micaceous, feldspathic, calcareous	3	10	331	1
Clay, buff gray mottled dark gray, flinty, brecciated; a few dark gray fragments have greenish cast. Lower Freeport	-	7	331	8
Clay, gray, plastic; becoming silty and ferruginous downward. Lower Freeport	4	8	336	4

Clay shale, dark gray; becoming silty downward		10	6	347	0
Sandstone, light gray, fine-grained, micaceous; in part calcareous, thin shale interbedded		15	0	362	0
Shale fine-grained to silty; several clay ironstone layers		4	0	366	0
Sandstone, white, micaceous, argillacecus; medium-grained, with shale streaks; partly calcareous		10	6	376	6
Shale, black, carbonaceous, with thin coal bands		-	2	376	8
Coal, bright, with pyrite and fusain bands	Middle Kittanning	-	11	377	7
Coal and black shale interbedded		-	3	377	10
Shale, dark gray, with thin coaly bands		1	0	378	10
Coal, bright, with several partings		1	3	380	1
Clay, dark gray, plastic, with carbonaceous streaks		4	11	385	0
Core missing		3	9	388	9
Shale, dark gray, fine to silty, with thin contorted micaceous sandy laminae; 1 inch carbonaceous shale at base		5	0	393	0
Sandstone, light gray; in part very coarse with angular grains of quartz and some dark clear gray feldspar to 1/4 inch; a few coal fragments		15	0	408	9
Coal, bright, with many thin pyrite bands; 1 inch bone at bottom		1	2	409	11
Clay, plastic, micaceous, impure		1	0	410	11
Shale, silty to sandy		2	6	413	5
Clay, dark gray, very silty; bottom 1 foot 6 inches with siderite concretions	Oak Hill	6	7	420	0
Shale, light gray, silty, passing into sandstone		5	0	425	0
Sandstone, white, fine to medium-grained		7	3	432	3
Shale, black, carbonaceous, Lower Kittanning coal horizon		2	0	434	3
Clay, light gray, plastic; becoming silty downward; many small siderite concretions		1	0	435	3
Clay, very dark gray, plastic		-	8	435	11

Clay, gray, plastic; becoming lighter and very siliceous downward and passing into siltstone	9	7	445	6
Clay, gray, plastic; becoming lighter and siliceous downward	4	0	449	6
Shale, gray, argillaceous, becoming silty downward	6	6	456	0
Siltstone, light gray, passing into	7	0	463	0
Sandstone, white, fine-to medium-grained, cross-bedded, laminated	28	0	495	0
Sandstone, white, medium to coarse-grained, cross-bedded; dark laminations; coaly streak at 501 feet; bottom 10 inches very calcareous	13	7	508	7
Shale, dark gray to black, fine-grained, becoming carbonaceous downward; thin layers and lenses of tan siderite	10	3	518	10
Coal, bright, with many bony layers, Tionesta?	1	7	520	3
Clay, dark gray, very sandy and micaceous	1	0	521	5
Siltstone and fine sandstone, laminated	7	3	528	8
Shale, dark gray, fine-grained, with a few thin coaly layers	3	4	532	0
Shale, dark gray, interlaminated with siltstone	5	0	537	0
Sandstone, fine-grained, laminated	3	0	540	0
Shale, dark gray, fine-grained, laminated	4	4	544	4
Shale, black, carbonaceous	-	2	544	6
Clay, gray, plastic	3	6	548	0
Clay, gray, silty	4	6	552	6
Shale, dark gray, fine-grained	3	0	555	6
Siltstone and fine sandstone, gray, with dark laminations; calcareous, 565-568 feet and 571-576 feet	20	6	576	0
Siltstone, dark gray, laminated	7	6	583	6
Sandstone, light gray, fine-grained, laminated, very calcareous	-	8	584	2
Sandstone, cross-bedded, and interbedded siltstone; some coal fragments	7	0	591	2
Coal, bright	-	1	591	3
Clay shale, dark gray to black, with thin coal streaks	9	3	600	6
Clay, dark gray, plastic	2	0	602	6
Clay shale, black, carbonaceous; siderite nodules in upper 2 inches	1	0	603	6
Clay, dark gray, plastic	2	0	605	6
Siderite, fine-grained, grayish tan	-	4	605	10
Clay shale, dark gray, with slickensides	5	8	611	6
Siltstone, dark, with contorted laminations; upper 4 inches with siderite nodules	3	8	615	2
Shale, black, carbonaceous	-	4	615	6
Coal, very bright	-	6	616	0

Clay, plastic, silty	3	0	619	0
Shale, inter-laminated, light and dark, silty	5	6	624	6
Shale, black, carbonaceous, silty	1	0	625	6
Coal, bright	-	6	626	0
Clay, micaceous, silty	1	6	627	6
Shale and siltstone passing into fine sandstone, laminated; very calcareous, 635-636 feet	9	6	636	0
Siltstone, micaceous, laminated; passing into fine shale downward	17	4	653	4
Shale, black, fine-grained, carbonaceous	1	6	654	10
Clay, gray, plastic, very silty and micaceous; passes downward into-	4	0	658	10
Siltstone and shale, interbedded	15	2	674	0
Sandstone, white, fine-grained, with darker laminations; passes downward to siltstone and shale	8	0	682	0
Limestone, gray, fine-grained, laminated; resembles siltstone	3	2	685	0
Siltstone, gray, laminated	16	5	701	7
Coal, bright	-	9	702	4
Clay, gray, plastic, silty and micaceous	2	6	704	10
Siltstone, gray, laminated; in part sandstone	9	2	714	0
Shale, dark gray; micaceous and silty at top, becoming darker and finer at base	7	0	721	0
Clay and clay shale, dark gray	1	6	722	6
Coal, bright, with bony streaks	-	7	723	1
Clay, gray, plastic, micaceous	2	11	726	0
Shale, gray, argillaceous; becomes silty and laminated downward	8	0	734	0
Sandstone, medium-grained, ferruginous	2	3	736	3
Sandstone, interbedded with black shale, "zebra striped;" below 775 more black shale, bedding very contorted; some calcareous sandstone streaks	55	9	792	0
Clay shale, gray, and in part greenish-gray	9	0	801	0
Siderite, gray-tan, calcareous, argillaceous <u>Harrison</u>	1	7	802	7
Clay shale, dark gray to greenish gray	1	0	803	7
Shale, red, fine-grained	-	6	804	1
Shale, dark gray to greenish gray	2	6	806	7
Shale, dark gray to black, fine-grained, fossiliferous, with several limestone layers 1/2 inch to 2 inches thick composed of shell fragments	8	9	815	4

<u>Maxville limestone</u>

Limestone, dark gray, fine-grained; very few shale partings	12	2	827	6
Shale, dark gray to black, calcareous	9	6	837	0
Limestone, buff gray, fine-grained, dense	4	0	841	0

Limestone, dark gray, argillaceous; passing downward to dark gray, calcareous shale	6	0	847	0
Shale, dark greenish gray, argillaceous, slightly calcareous	-	9	847	9
Limestone, gray to gray brown, fossiliferous, highly siliceous	-	6	848	3
Shale, greenish gray, argillaceous, slightly calcareous	-	1 1/2	848	4 1/2
Limestone, granular to crystalline, gray to light brown gray, compact, slightly fossiliferous, apparently thick-bedded	22	7 1/2	871	0
Limestone, gray to brownish gray, finely crystalline to dense, compact, sparingly fossiliferous, with a few thin zones a fraction to 2 inches in thickness of dark bluish brown, dense limestone	11	6	882	6
Limestone, gray to brown, generally dense, showing only a few crystals	12	0	894	6
Limestone, brownish gray, in part coarsely crystalline	2	5	896	11
Limestone, brown to gray black, generally dense	-	6	897	5
Shale, greenish gray to gray black, calcareous	1	0	898	5
Limestone, gray to light buff, dense, highly dolomitic, somewhat siliceous	2	9	901	3
Limestone, gray to brownish gray, dense, slightly dolomitic, breaks with sub-conchoidal fracture	2	3	903	6
Limestone, gray, dense and stony, compact, dolomitic	2	4	905	10
Limestone, dark gray to brown, dense, breaks with sub-conchoidal fracture	4	0	909	10
Limestone, dark gray to brown, dense and tough, dolomitic	-	8	910	6
Limestone, gray, fine-grained, in part dolomitic	12	6	923	6
Limestone, white, with darker argillaceous layers, sandy	9	6	933	0
Sandstone, white to light gray, very fine-grained	8	0	941	0
Sandstone, white, very fine-grained, interbedded with very fine shale	20	0	961	0
Total			961	0

The heavy-bedded Maxville limestone was first encountered in this test at a depth of about 815 feet and extended with a few shale breaks to a depth of 933 feet. Analyses of 21 samples of Maxville limestone from this core supplied to the Survey through the courtesy of Mr. L. P. Barrett, of the Jones and Laughlin Ore Company, are given below.[1]

[1] *Price, Paul H., Possibilities of shaft mining of Greenbrier limestone: W. V. Geol. and Econ. Survey, Rept. Inv. No. 6., p. 13, 1948.*

Chemical analyses of Maxville limestone from Hole No. 2 by Jones and Laughlin Ore Company, Section 15, Addison Township, Gallia County, analyses from laboratories of Jones and Laughlin Ore Company.

Footage	Thickness Ft.	Silica SiO_2	P_2O_5	Calcium Carbonate $CaCO_3$	Magnesium Carbonate $MgCO_3$	Sulphur	Phosphorus	Moisture
815-817	2	9.86	4.30	81.62	2.42	0.708	0.019	--
817-821	4	3.96	1.24	92.60	1.90	0.269	0.009	--
821-824 1/2	3 1/2	5.00	1.78	92.40	1.67	0.217	0.005	--
824 1/2-828	3 1/2	14.66	4.98	75.30	3.27	0.403	0.008	--
837-841	4	4.74	1.72	84.36	9.10	0.041	0.006	4
848 1/2-851	2 1/2	2.82	2.22	80.88	14.19	0.039	0.018	--
851-856	5	3.26	1.44	88.75	7.12	0.029	0.007	--
856-861	5	4.16	1.90	88.70	4.69	0.027	0.008	--
861-866	5	1.86	1.20	92.63	4.54	0.029	0.007	--
866-871	5	4.56	2.16	83.53	9.66	0.053	0.013	--
871-876	5	7.34	2.94	81.98	7.23	0.059	0.013	--
876-881	5	8.00	3.18	83.81	4.73	0.059	0.009	--
881-886	5	8.02	2.96	85.41	3.85	0.062	0.009	--
886-891	5	7.10	2.76	85.27	4.39	0.067	0.010	--
891-896 1/2	5 1/2	6.80	2.96	83.90	5.98	0.561	0.012	--
896 1/2-897 1/2	1	33.50	16.10	32.38	14.96	0.780	0.096	1.10
897 1/2-900 1/2	3	7.26	2.66	63.87	25.68	0.144	0.028	--
900 1/2-905 1/2	5	9.20	3.76	67.35	18.80	0.172	0.022	--
905 1/2-910 1/2	5	9.56	3.44	83.08	3.33	0.152	0.019	--
910 1/2-921	10 1/2	2.68	1.16	92.96	2.87	0.178	0.016	--
921-923	2	10.06	3.26	77.22	9.50	0.431	0.012	--
Av. 815-828	13	8.03	2.73	86.20	2.29	0.359	0.009	--
Av. 848 1/2-896 1/2	48	5.44	2.39	85.71	6.24	0.106	0.010	--
Av. 897 1/2-923	25 1/2	6.43	2.46	81.34	9.29	0.188	0.019	--
Av. 848 1/2-923	74 1/2	6.16	2.60	83.50	7.40	0.143	0.014	--

In test hole No. 10-A drilled on the Bradbury property in Section 20, Addison Township, the Maxville limestone was first encountered at a depth of 871 feet and continued with a few thin shale breaks to a depth of 986 feet 10 inches. According to preliminary tests by Jones and Laughlin Ore Company, the silica content in the upper 12 feet or so of the Maxville is nearly 3 per cent less in test No. 10-A than in test No. 2. In the lower 25 feet or so of the limestone, however, the silica content is nearly 2.5 per cent greater in the core from test No. 10-A.

Zaleski Member

Exposures of the Zaleski member are confined to the northwestern corner of Greenfield Township where it is represented by iron ore.

Vanport Limestone

Outcrops of this limestone are confined to the valleys of Raccoon Creek in sections 18 and 7, Huntington Township, and to Black Fork and its tributaries in the northwest quarter of Greenfield Township. The thickness of limestone on the outcrop varies in these areas from 5 to 7 feet. It has been quarried near Gallia, Greenfield Township, and utilized as agricultural lime. For approximate composition of this limestone see analysis of samples secured in Madison Township, Jackson County, and Washington Township, Lawrence County.

Brush Creek Limestone

The Brush Creek member in Gallia County is represented by two thin limestones separated by 20 feet or more of shale. "The lithologic character of these limestones varies greatly from place to place. The composition changes from a quite pure limestone through ferruginous, siliceous limestone to a flinty material, containing but little calcium and magnesium carbonates. The upper layer where only about 1 foot in thickness is usually rather pure, but where it thickens to several feet it is shaly and flinty in character.... The shales in the interval between the two limestone beds often assume a calcareous, siliceous phase. The lower limestone bed usually has a thickness of about 1 foot, although in a few localities it expands to 2 or 3 feet. The composition of this bed resembles very much that of the upper one."[1] The area over which the Brush Creek limestone outcrops in Gallia County includes western Morgan and western Springfield townships, Huntington and Raccoon townships east of Raccoon Creek, much of Perry Township, and western Walnut and southeastern Greenfield townships. Along the valley of Sand Fork in eastern Walnut Township and in Raccoon and Huntington townships west of Raccoon Creek this member is generally wanting. Where the Brush Creek beds occur the upper limestone is generally the thicker of the two and it is far more regular and persistent on the outcrop. Quarries have operated in this limestone at a number of places along the outcrop chiefly for the production of road stone.

In 1942 the Brush Creek limestone was being quarried by Ray Grover in the northwest quarter of Section 21, Springfield Township, and was being marketed for road stone. The quarry is located along the creek 1 mile due west of Evergreen. Some 20 feet higher on the hill to the north is an old pit where Mr. Grover formerly worked the Cambridge limestone for agricultural lime. The rock exposures at this locality are described as follows:

		Ft.	In.
Sandstone		10	0
Limestone, bluish gray, somewhat resinous in appearance, Cambridge		2	6
Covered interval		20	8
Shale, yellowish brown, ferruginous		5	0
Limestone, bluish gray, dense, sampled	Brush Creek	-	10
Shale, calcareous, not sampled	Brush Creek	-	1
Limestone, bluish gray, dense, compact, brittle, sampled	Brush Creek	-	6
Shale, calcareous, not sampled	Brush Creek	-	1
Limestone, bluish gray, dense, compact, brittle, sampled	Brush Creek	-	4
Shale, calcareous, not sampled	Brush Creek	-	1/2

[1] *Stout, Wilber, Geology of Southern Ohio: Geol. Survey Ohio Bull. 20, p 653, 1916.*

		Feet	Inches
Limestone, bluish gray, dense, brittle, sampled....	Brush Creek (cont.)	-	5
Shale, calcareous, not sampled........		-	3
Limestone, bluish gray, dense, sampled		-	8
Shale, dark bluish gray, calcareous, not sampled........		-	4
Limestone, bluish gray to brownish gray, dense, irregular layer, sampled		1	4
Shale, bluish gray, calcareous, not sampled		1	1
Stream level.			

The layers of Brush Creek limestone having a total thickness of 4 feet 1 inch were sampled by R. E. Lamborn on September 30, 1942, for chemical analysis.

Sample No. 397

Chemical analysis of Brush Creek limestone from quarry of Ray Grover, Section 21, Springfield Township, Gallia County, Nalin Laboratories, analysts.

	Per cent
Silica, SiO_2	45.00
Alumina, Al_2O_3	6.40
Ferric oxide, Fe_2O_3	0.63
Ferrous oxide, FeO	0.58
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.49
Calcium oxide, CaO	22.98
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.25
Potassium oxide, K_2O	0.48
Water, hydroscopic, H_2O-	0.18
Water, combined, H_2O+	1.35
Carbon dioxide, CO_2	21.30
Titanium dioxide, TiO_2	0.02
Phosphorus pentoxide, P_2O_5	0.03
Sulphur trioxide, SO_3	0.06
Manganous oxide, MnO	0.01
Carbon, organic, C	0.34
Hydrogen, organic, H	0.06
Total	100.16

The per cent of each of the mineral components in the sample as computed (Lamborn) from the chemical analysis is as follows:

Silicates $(Na, K)_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$	7.14
Silicates $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	9.13
Silica, SiO_2	37.46
Hydrated ferric oxide, $2Fe_2O_3 \cdot 3H_2O$	0.74

Ferrous carbonate, $FeO.CO_2$	0.93
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO.P_2O_5$	0.06
Calcium sulphate, $CaO.SO_3$	0.10
Calcium carbonate, $CaO.CO_2$	40.88
Magnesium carbonate, $MgO.CO_2$	1.02
Manganese carbonate, $MnO.CO_2$	0.02
Water, hydroscopic, H_2O-	0.18
Organic matter	0.40
Unbalanced components (deficiency CO_2, H_2O)	+2.08
Total	100.16

Cambridge Limestone

The Cambridge is the most prominent of the limestones of the Conemaugh series exposed at the surface in Gallia County. Its field of outcrops includes western Morgan and western Springfield townships, Raccoon and Huntington townships east of Raccoon Creek, Perry Township and southeastern Greenfield townships, western Walnut Township, and the valleys of Sand Fork and Raccoon Creek in western Walnut and southwestern Green townships respectively. Where typically developed in this county the Cambridge limestone is a dark gray, dense, noncrystalline rock, with dark, indistinct, wavy laminations and a few thin, flinty seams along the bedding lines. The flint is apparently of secondary origin; that is, it was formed along the bedding lines subsequent to the deposition of the limestone. Fossils at the contact are often half flint and half calcite. The Cambridge limestone may easily be confused with the Brush Creek beds lying a little lower, as those are somewhat similar in texture in some localities."[1] The thickness of the Cambridge varies from 1 foot to 4 feet with an average for the county of about 2 feet. Quarries have operated in this limestone at various times near Northup, Rodney, Patriot, Rio Grande, and Bidwell. Its chief utilization is for crushed stone products and for agricultural lime.

A quarry in the Cambridge limestone operated by Ray Grover of Vinton is located at the head of a small ravine along the west central edge of Section 25, Morgan Township. Pulverized limestone for use in agriculture is the chief product of the operation. The beds exposed in the quarry are described as follows:

		Ft.	In.
Clay shale		-	-
Shale, reddish to light olive in color		2	0
Limestone, bluish to brownish gray, dense to finely crystalline, fossiliferous	Cambridge	-	8
Limestone, bluish to brownish gray, dense to finely crystalline, fossiliferous, somewhat nodular	Cambridge	2	4
Bottom of quarry.			

The 3-foot bed of Cambridge limestone exposed here was sampled for chemical analysis on September 18, 1942, by R. E. Lamborn.

[1] *Condit, D. D., op. cit., p. 79.*

Sample No. 395

Chemical analysis of Cambridge limestone from quarry of Ray Grover, Section 25, Morgan Township, Gallia County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	5.11
Alumina, Al_2O_3	0.26
Ferric oxide, Fe_2O_3	0.20
Ferrous oxide, FeO	0.67
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.70
Calcium oxide, CaO	51.26
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.10
Potassium oxide, K_2O	0.16
Water, hydroscopic, H_2O-	0.05
Water, combined, H_2O+	0.03
Carbon dioxide, CO_2	41.27
Titanium dioxide, TiO_2	0.02
Phosphorus pentoxide, P_2O_5	0.02
Sulphur trioxide, SO_3	0.24
Manganous oxide, MnO	0.03
Carbon, organic, C	0.18
Hydrogen, organic, H	0.02
Total	100.32

The per cent of each of the mineral components probably present in the sample as computed (Lamborn) from the chemical analysis follows:

Silica and hydrated aluminum silicates of sodium and potassium	5.63
Hydrated ferric oxide, $2Fe_2O_3 \cdot 3H_2O$	0.23
Ferrous carbonate, $FeO \cdot CO_2$	1.08
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO \cdot P_2O_5$	0.04
Calcium sulphate, $CaO \cdot SO_3$	0.41
Calcium carbonate, $CaO \cdot CO_2$	91.15
Magnesium carbonate, $MgO \cdot CO_2$	1.46
Manganese carbonate, $MnO \cdot CO_2$	0.05
Water, hydroscopic, H_2O-	0.05
Organic matter	0.20
Unbalanced components (CO_2, H_2O)	0.00
Total	100.32

Miller Brothers of Gallipolis have operated a quarry in the Cambridge limestone for a number of years near Gage in Perry Township. The quarry is situated at the east edge of Section 28, just north of State Route No. 141 and about 1 1/2 miles northwest of Patriot. The chief products of the quarry are crushed stone for road construction and repair and pulverized limestone for use in agriculture. The rock exposures in the quarry are described as follows:

		Ft.	In.
Shale, weathered		10	-
Limestone, bluish to brownish gray, dense texture, sampled	Cambridge	-	4

Limestone, bluish to light brownish gray, with zones and nodules of chert, not sampled........	Cambridge (cont.)	....	-	8
Limestone, bluish to brownish gray, dense, in nodular layers 2 to 6 inches thick, sampled		....	2	2
Shale, greenish gray, calcareous, not sampled		....	-	2
Limestone, bluish to light brownish gray, generally dense, sampled		....	-	7
Bottom of quarry.				

Limestone as it comes from the quarry is crushed for road mettle whereas the part relatively free from chert is utilized for agricultural lime. The member as described above, excluding the 8-inch cherty zone near the top, was sampled for chemical analysis on September 30, 1942, by R. E. Lamborn.

Sample No. 398

Chemical analysis of Cambridge limestone from quarry of Miller Brothers, Section 28, Perry Township, Gallia County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	11.70
Alumina, Al_2O_3	1.71
Ferric oxide, Fe_2O_3	0.27
Ferrous oxide, FeO	0.62
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.80
Calcium oxide, CaO	45.46
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.08
Potassium oxide, K_2O	0.16
Water, hydroscopic, H_2O-	0.07
Water, combined, H_2O+	0.57
Carbon dioxide, CO_2	38.04
Titanium dioxide, TiO_2	<0.01
Phosphorus pentoxide, P_2O_5	0.03
Sulphur trioxide, SO_3	0.19
Manganous oxide, MnO	0.03
Carbon, organic, C	0.13
Hydrogen, organic, H	0.02
Total	99.89

The per cent of each of the mineral components probably present in the sample as computed (Lamborn) from the chemical analysis is given below:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	2.34
$Al_2O_3.2SiO_2.2H_2O$	2.02
Silica, SiO_2	9.68

Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.31
Ferrous carbonate, $FeO.CO_2$	1.00
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	<0.01
Calcium phosphate, $3CaO.P_2O_5$	0.06
Calcium sulphate, $CaO.SO_3$	0.33
Calcium carbonate, $CaO.CO_2$	80.84
Magnesium carbonate, $MgO.CO_2$	1.67
Manganese, carbonate, $MnO.CO_2$	0.05
Water, hydroscopic, H_2O-	0.07
Organic matter	0.15
Unbalanced components (deficiency CO_2, H_2O)	+1.36
Total	99.89

Portersville Member

The Portersville member in this county is a discontinuous impure ferruginous layer measuring only a few inches in thickness and has no economic importance.

Ames Limestone

The Ames limestone lacks economic importance in this county, where Condit has described its character and distribution as follows.[1]

"Unfortunately the Ames limestone in Gallia County is not the easily recognized, persistent bed so prominent in Athens and other counties to the north. It is present in most localities north of Gallipolis, but was found at only a few places anywhere south of that city. At best it is only a ferruginous, impure, sandy limestone about 1 foot thick, and in some outcrops was found to be a calcareous, fossiliferous sandstone."

Ames limestone 2 feet in thickness is found over small local areas in Morgan Township.

GEAUGA COUNTY

General Considerations

Geauga County embracing an area of about 409 square miles is located in the northern part of the glaciated section of the Allegheny Plateau. The bedrocks which reach the surface in this county consist chiefly of conglomerates, sandstones, and shales having a total combined thickness approaching 800 feet. The subdivisions represented in the outcrops include the Chagrin and Cleveland shales of Upper Devonian age, the Bedford, Berea, Sunbury, and Cuyahoga formations of Mississippian age, and 200 feet or more of Pottsville strata of Pennsylvanian age. Some thin coal has been reported in the Pottsville series.[2] No limestone beds are known to outcrop in this county. Deep-seated limestones of Middle Devonian age are reached in wells at depths below sea level ranging from 800 feet in the northwestern corner to 1,200 feet in the southeastern corner of the county.

[1] *Op. cit., pp. 78-79.*

[2] *Read, M. C. Geology of Geauga County: Geol. Survey Ohio Vol. I, P.I., pp. 521-522, 1873.*

GUERNSEY COUNTY

General Considerations

The bedrocks which reach the surface within the boundary limits of Guernsey County include the upper part of the Pottsville series, the Allegheny series, the Conemaugh series, and the lower 150 feet or so of the Monongahela series, all of Pennsylvanian age. Due to the rough and rugged topography, so characteristic of the maturely dissected, unglaciated portion of the Allegheny Plateau of which this county is a part, the rock outcrops are numerous and widely distributed over the area. The beds of the upper Pottsville and lower Allegheny series are found close to drainage level in Wheeling Township in the northwest corner but, as the regional inclination of the strata is south of east across the county, these members soon pass below drainage in that direction beneath younger and overlying strata. The Conemaugh series has the greatest areal distribution in the county whereas the outcrops of the Monongahela series are confined to the high hills and ridges in the eastern and southeastern parts. The total thickness of the beds outcropping in Guernsey County, which embraces an area of 527 square miles, is approximately 860 feet. A generalized section of the strata prepared from published data [1] and from field notes by Wilber Stout and R. E. Lamborn is given below:

Generalized Section of Bedrocks Outcropping in Guernsey County

		Ft.	In.
Pennsylvanian system			
Monongahela series			
Sandstones and sandy shales, Upper Sewickley sandstone horizon		35	0
Coal, in many places shaly, Meigs Creek or No. 9		3	6
Sandstone and shale, Lower Sewickley sandstone horizon		46	7
Coal, shaly, and carbonaceous shale, Fishpot		1	3
Shale, calcareous, with some beds of light-colored, dense limestone interstratified, Fishpot limestone horizon		37	0
Sandstone and sandy shale, Pittsburgh sandstone horizon		27	0
Coal, shaly, locally present	Pittsburgh or No. 8	--	3
Parting		--	3
Coal		--	8
Parting		--	1 1/2
Coal		--	5
Parting		--	1/4
Coal		1	8
Parting		--	1/4
Coal		1	0
Conemaugh series			
Clay, with one or more layers of limestone, Pittsburgh		5	0
Shale, sandy		6	0

[1] *Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17, pp. 168-169, 1912.*

Clay, with a few layers of limestone	30	0
Sandstone, shaly, Bellaire	16	0
Limestone, several layers, interlain with clay, Summerfield	4	0
Sandstone, shaly, Connellsville	18	0
Shale, argillaceous to arenaceous; red beds with nodules of limestone and hematite common	58	0
Shale, with layers of impure limestone, Skelley horizon	25	0
Shale, argillaceous	16	0
Limestone, greenish gray, fossiliferous, Ames	2	0
Shale	12	0
Coal, Harlem	--	6
Clay, gray	2	0
Shale	22	0
Coal, local Barton	--	2
Clay with limestone nodules, Ewing horizon	14	0
Sandstone, local, and arenaceous shale, Cow Run sandstone horizon	38	0
Shale, dark, fossiliferous, local, Portersville horizon	3	0
Coal, shaly, and black shale, Anderson	1	7
Clay, with nodules of limestone	6	10
Shale, argillaceous	7	4
Limestone, fossiliferous, ferruginous, arenaceous, Cambridge	1	0
Coal, shaly, and black shale, Wilgus	--	2
Clay, bluish gray	5	8
Sandstone, and arenaceous shale, Buffalo sandstone horizon	37	8
Shale, dark, arenaceous, with occasional nodules of black limestone locally present, Brush Creek beds	6	10
Coal, shaly, locally present, Brush Creek	--	11
Clay, bluish gray, local	3	0
Shale, arenaceous	12	0
Shale, black, carbonaceous, Mason	--	6
Clay, shaly	--	5
Sandstone, shaly, and arenaceous shale, Upper Mahoning sandstone horizon	22	5
Coal and black shale, locally present, Mahoning	--	8
Clay, gray, with some limestone nodules	5	11
Sandstone, somewhat shaly, and arenaceous shale, Mahoning sandstone horizon	45	9

Allegheny series

Coal, good	Upper Freeport or No. 7	3	6
Parting		--	1 3/8
Coal, good		1	6
Clay, gray, calcareous		3	9
Limestone, gray, somewhat nodular, Upper Freeport		--	8
Sandstone and arenaceous shale, Upper Freeport sandstone horizon		45	7
Coal, local, Lower Freeport		--	6

Clay, gray, calcareous		5	0
Sandstone, local, and arenaceous shale		39	0
Shale, black, and shaly coal	Middle Kittanning or No. 6	--	4
Coal, good		2	10
Parting		--	2
Coal, good		--	9
Clay, bluish gray, arenaceous		8	7
Shale, bluish gray, arenaceous		19	1
Limestone, dark, fossiliferous, local, Hamden		--	6
Shale, dark		--	8
Coal, Lower Kittanning or No. 5		2	0
Clay, bluish gray, plastic		10	0
Shale, bluish gray, arenaceous		38	10
Limestone, bluish gray, fossiliferous, Putnam Hill		1	0
Pottsville series			
Shale and covered, estimated thickness		75	0

Eleven limestone members have been recognized in the rock series outcropping in Guernsey County. Named in ascending order these include the Putnam Hill, Hamden, Upper Freeport, Brush Creek, Cambridge, Ewing, Ames, Skelley, Summerfield, Pittsburgh, and Fishpot limestones. Due to their limited distribution and poor development or discontinuous nature, many of these members are worthy of little discussion here. Within recent years limestone production for road construction and for agricultural use has been secured in this county chiefly from quarries operating in the Cambridge, Ames, and Summerfield members and located in Adams, Valley, Center, Wills, and Oxford townships.

No limestone beds of possible economic importance are known to occur close below the lowest strata outcropping in this county. The Maxville limestone, which in normal succession for Ohio immediately underlies the Pottsville, has not been recognized in any of the widely scattered wells drilled in Guernsey County. In descending order the next important limestone or group of limestones and dolomites, variously known to the driller as the "Niagara lime" or Big Lime, is first encountered at depths below sea level ranging from approximately 2,050 feet in the northwest corners of Wheeling and Knox townships to about 3,500 feet in the southeast corner of Millwood Township.

Putnam Hill Limestone

The distribution of the outcrops of the Putnam Hill limestone in Guernsey County is confined chiefly to the Wills Creek Valley below Kimbolton, to the valley of Birds Run in the western half of Wheeling Township, and to the valley of the large tributary to Wills Creek in the northwestern corner of Wheeling Township. Outcrops of limestone in this area indicate that the member is thin and is lacking in exceptional quality. The stone was formerly quarried on a small scale near Kimbolton and burned for lime.[1] It is not being utilized at the present time.

[1] *Orton, Edward, Economic geology of Ohio: Geol. Survey Ohio Vol. V, p. 283, 1884.*

Hamden Limestone

The Hamden limestone, which normally occurs close above the lower Kittanning coal, has no economic importance in Guernsey County as its known distribution is limited to a few localities in Wheeling Township where it measures only a few inches in thickness.

Upper Freeport Limestone

The Upper Freeport limestone measuring 1 foot or less in thickness is present on the outcrop at several scattered localities in Wheeling and Liberty townships. Elsewhere in the county it is generally wanting.

Brush Creek Member

The Brush Creek beds in Guernsey County are typical for this member in eastern Ohio in that they consist chiefly of black, carbonaceous, fossiliferous shale with occasional nodules or thin layers of hard, black limestone embedded in the lower part. In this county the limestone is, in general, poorly developed. Outcrops of this horizon are due above drainage over large areas in the northwestern half of the county but sandstone and sandy shale have replaced the Brush Creek over much of this area.

Cambridge Limestone

Outcrops of the Cambridge limestone are widely distributed in Guernsey County as they are present in every township with the exception of Londonderry, Oxford, and Millwood located along the eastern boundary. The position of the member in this area is on an average about 147 feet above the horizon of the Upper Freeport coal and about 108 feet below the Ames limestone. As generally developed on the outcrop the Cambridge is gray to yellowish gray, dense-textured, ferruginous, fossiliferous limestone which tends to be nodular in character. The usual thickness on the outcrop varies from a few inches to about 2 feet. An exceptional thickening of the member, however, is found in Adams, southwestern Cambridge, and northern Westland townships where the stone is bluish to greenish gray in color, siliceous in composition, somewhat nodular in character, and measures 5 feet or more in thickness. The Cambridge was formerly quarried for road stone one-half mile east of High Hill School in the southwest part of Cambridge Township. It has likewise been quarried for road purposes in the northwest quarter of Section 24, Adams Township, and near Lore City in Richland Township. The stone from these quarries is hard and dense, has a low absorption, and withstands abrasion well. The Cambridge in this area is not adapted to uses where a high per cent of calcium carbonate is required. For an analysis of the Cambridge limestone see Sample No. 344 taken in Highland Township, Muskingum County.

Ewing Limestone

The horizon of the Ewing limestone, occurring about midway between the Cambridge and Ames limestones, is occupied over much of the outcrops in Guernsey County by sandstones and sandy shale. In the absence of these clastic beds, the Ewing is represented by thin nodular limestone in places brecciated in character embedded in calcareous clays. For an analysis of the limestone see pages of this report dealing with the Ewing limestone in Noble County.

Ames Limestone

The chief field of outcrops of the Ames limestone in Guernsey County includes the southern part of Westland Township, northern Spencer, and southwestern Valley townships and an area extending from Washington and Londonderry townships on the north to Richland Township on the south. In this field the position of the member is on an average about 108 feet above the Cambridge limestone previously described and, in the eastern part of the county, about 180 feet below the Pittsburgh coal. The thickness of the limestone varies from 0 to about 5 feet with an average of about 2 feet. The stone is typical in its structural features and it is generally represented on the outcrop by one or more hard layers of stone overlain and underlain by shale. The Ames occurs in good development along the valley of Yoker Creek in eastern Spencer Township and in the southwestern part of Valley Township. A description of the outcrops of the Ames limestone just south of Bluebell in the northern part of Section 13, Valley Township, where the stone was formerly quarried for road purposes, is as follows:

		Ft.	In.
Soil and weathered shale		3	0
Shale, yellowish brown	Ames	10	0
Limestone, pink to gray, somewhat crystalline, one layer	Ames	2	9
Limestone, bluish gray, dense in texture, one layer	Ames	2	0
Shale		--	--

On July 2, 1941, the Ames limestone at this locality was sampled by R. E. Lamborn for chemical analysis.

Sample No. 357

Chemical analysis of Ames limestone from old quarry near Bluebell, Section 13, Valley Township, Guernsey County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	4.77
Alumina, Al_2O_3	1.48
Ferric oxide, Fe_2O_3	0.04
Ferrous oxide, FeO	2.02
Iron disulphide, FeS_2	0.30
Magnesium oxide, MgO	0.75
Calcium oxide, CaO	48.68
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.03
Potassium oxide, K_2O	0.11
Water, hydroscopic, H_2O-	0.28
Water, combined, H_2O+	0.38
Carbon dioxide, CO_2	40.47
Titanium dioxide, TiO_2	0.04
Phosphorus pentoxide, P_2O_5	0.10
Sulphur trioxide, SO_3	0.06
Manganous oxide, MnO	0.60
Carbon, organic, C	0.02

Hydrogen, organic, H	--
Total	100.13

The per cent of each of the mineral compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.30
Silicates $Al_2O_3.2SiO_2.2H_2O$	2.47
Silica, SiO_2	3.03
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	3.25
Iron disulphide, FeS_2	0.30
Titanium dioxide, TiO_2	0.04
Calcium phosphate, $3CaO.P_2O_5$	0.22
Calcium sulphate, $CaO.SO_3$	0.10
Calcium carbonate, $CaO.CO_2$	86.60
Magnesium carbonate, $MgO.CO_2$	1.57
Manganese carbonate, $MnO.CO_2$	0.97
Water, hydroscopic, H_2O-	0.28
Organic matter	0.02
Unbalanced components (excess CO_2, H_2O)	-0.06
Total	100.13

Skelley Limestone

No economic importance can be attached to the Skelley limestone in Guernsey County where the member is represented by only occasional thin deposits of nodular limestone embedded in calcareous shales occurring from 15 to 20 feet above the Ames limestone.

Summerfield Limestone

Outcrops of the Summerfield limestone in Guernsey County are confined for the most part to Oxford, Millwood, Richland, and Wills townships and to southern Londonderry and southwestern Spencer townships. In this area the limestone is a persistent member consisting of light bluish to brownish gray dense-textured stone having a maximum thickness approaching 10 feet. Its stratigraphic position varies from 30 to 60 feet below the Pittsburgh coal and from 120 to 250 feet above the Ames limestone.

The Summerfield has long been the chief limestone quarried in the eastern part of Guernsey County. It was formerly worked by stripping north of Senecaville, in Section 12, Richland Township, where it was crushed for road stone. Concerning its qualities Morse writes as follows:[1]

"In terms of standard surface macadam stone the limestone of this quarry has a medium resistance to abrasion, excellent concreting properties, superior hardness, and low toughness. The limestone more than meets all the requirements of the department for such purposes and for a coarse aggregate for any kind of a concrete road. In fact it is one of the better stones of the state."

Summerfield limestone secured from quarries a mile or so south of Lore City was formerly shipped in car load lots to Canal Dover where it was utilized as furnace flux.

[1] *Morse, W. C., Road Materials of Ohio: (unpublished manuscript) State Highway Testing Laboratory, Columbus, p. 384, 1935.*

In Wills Township outcrops of Summerfield limestone are confined to the upper slopes along the high ridge extending to the southeast from Elizabethtown in Section 14. Exposures of this limestone on the Maude Laughman property near the ridge road in the west central part of Section 13, are described as follows:

		Ft.	In.
Shale, yellowish, calcareous		18	0
Limestone, brownish gray, dense-textured, one layer	Summerfield	--	10
Limestone, brownish gray, dense-textured, one layer	Summerfield	1	3
Limestone, brownish gray, dense-textured, one layer	Summerfield	1	0
Limestone, brownish gray, dense-textured, one layer	Summerfield	--	8
Covered interval		135	0
Limestone, greenish gray, crystalline, Ames		--	9

The Summerfield limestone at this locality having a thickness of 3 feet 9 inches has been quarried and crushed for agricultural use by the co-op Stone Company of Cambridge, Ohio. A sample of the stone was secured by R. E. Lamborn for chemical analysis on July 1, 1941.

Sample No. 355

Chemical analysis of Summerfield limestone from quarry of the Co-op Stone Company, Section 13, Wills Township, Guernsey County, Analyst, Downs Schaaf

	Per cent
Silica, SiO_2	2.20
Alumina, Al_2O_3	0.06
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.32
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.92
Calcium oxide, CaO	52.95
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	0.01
Water, hydroscopic, H_2O-	0.22
Water, combined, H_2O+	0.02
Carbon dioxide, CO_2	42.88
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.03
Sulphur trioxide, SO_3	0.07
Manganous oxide, MnO	0.33
Carbon, organic, C	0.03
Hydrogen, organic, H	--
Total	100.07

The per cent of each of the chemical compounds probably present in Sample No. 355 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.08
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.07
Silica, SiO_2	2.13
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	0.52
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.01
Calcium phosphate, $3CaO.P_2O_5$	0.07
Calcium sulphate, $CaO.SO_3$	0.12
Calcium carbonate, $CaO.CO_2$	94.36
Magnesium carbonate, $MgO.CO_2$	1.92
Manganese carbonate, $MnO.CO_2$	0.53
Water, hydroscopic, H_2O-	0.22
Organic matter	0.03
Unbalanced components (excess CO_2, H_2O)	-0.01
Total	100.07

In 1941 the Summerfield limestone was being quarried in the west central part of Section 11, Oxford Township, by H. A. Thompson of Quaker City, Ohio. The part of the member utilized has a thickness of nearly 8 feet and yields a stone of good purity. Road stone and pulverized limestone for agricultural purposes are the sole products. The following is a description of the outcrops at this locality:

Mine level, Pittsburgh coal horizon		Ft.	In.
Covered interval		15	0
Limestone, dark, ferruginous		--	9
Clay shale, dark, soft		2	6
Clay, shaly, with nodules of dark ferruginous limestone		2	3
Limestone, bluish gray, somewhat brecciated	Summerfield	--	10
Limestone, light bluish brown, with many calcite veins	Summerfield	1	8
Limestone, light bluish brown, brittle, with calcite veins	Summerfield	4	11
Limestone, light bluish brown	Summerfield	--	4

Bottom of pit, altitude 1,032 feet.

The Summerfield limestone in this quarry having a thickness of 7 feet 9 inches was sampled on July 1, 1941, by R. E. Lamborn for chemical analysis.

Sample No. 356

Chemical analysis of Summerfield limestone from quarry operated by H. A. Thompson, Section 11, Oxford Township, Guernsey County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	2.72
Alumina, Al_2O_3	0.14

Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.49
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.47
Calcium oxide, CaO	52.99
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	0.01
Water, hydroscopic, H_2O-	0.21
Water, combined, H_2O+	0.04
Carbon dioxide, CO_2	42.50
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.06
Sulphur trioxide, SO_3	0.02
Manganous oxide, MnO	0.29
Carbon, organic, C	0.03
Hydrogen, organic, H	--
Total	100.00

The per cent of each of the chemical compounds probably present in Sample No. 356 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.08
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.27
Silica, SiO_2	2.56
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	0.79
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.01
Calcium phosphate, $3CaO.P_2O_5$	0.13
Calcium sulphate, $CaO.SO_3$	0.03
Calcium carbonate, $CaO.CO_2$	94.43
Magnesium carbonate, $MgO.CO_2$	0.98
Manganese carbonate, $MnO.CO_2$	0.47
Water, hydroscopic, H_2O-	0.21
Organic matter	0.03
Unbalanced components (excess CO_2, H_2O)	-0.01
Total	100.00

During the summer of 1943 H. A. Thompson of Quaker City opened a quarry in the Summerfield limestone in the south central part of Section 14, Oxford Township, for the production of lime for agricultural use. The rock exposures at this locality are described below.

		Ft.	In.
Shale, estimated thickness		8	0
Coal, good	Pittsburgh or No. 8	--	10
Clay shale parting	Pittsburgh or No. 8	--	2
Coal, good	Pittsburgh or No. 8	2	2
Covered interval		34	0
Limestone, gray to light bluish or brownish gray, dense, somewhat brittle, cut with minute calcite veins	Summerfield	3	0

Limestone, gray to light brownish gray, hard, with minute veins of calcite	Summerfield (cont.)		1	1
Shale, yellowish, calcareous			2	0

The Summerfield limestone as described above having a total thickness of 4 feet 1 inch was sampled by R. E. Lamborn for chemical analysis on October 7, 1943.

Sample No. 432

Chemical analysis of Summerfield limestone from quarry operated by H. A. Thompson, Section 14, Oxford Township, Guernsey County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	5.28
Alumina, Al_2O_3	0.67
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	1.40
Iron disulphide, FeS_2	0.49
Magnesium oxide, MgO	2.34
Calcium oxide, CaO	48.08
Sodium oxide, Na_2O	0.04
Potassium oxide, K_2O	0.05
Water, hydroscopic, H_2O-	0.08
Water, combined, H_2O+	0.45
Carbon dioxide, CO_2	40.76
Titanium dioxide, TiO_2	0.02
Phosphorus pentoxide, P_2O_5	0.08
Sulphur trioxide, SO_3	0.03
Manganous oxide, MnO	0.28
Total	100.07

The per cent of each of the mineral components in Sample No. 432 as determined by calculation (Lamborn) from the chemical analysis is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.92
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.79
Silica, SiO_2	4.49
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	2.26
Iron disulphide, FeS_2	0.49
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO.P_2O_5$	0.17
Calcium sulphate, $CaO.SO_3$	0.05
Calcium carbonate, $CaO.CO_2$	85.61
Magnesium carbonate, $MgO.CO_2$	4.89
Manganese carbonate, $MnO.CO_2$	0.45
Water, hydroscopic, H_2O-	0.08
Unbalanced components, (excess CO_2, H_2O)	-0.17
Total	100.07

Pittsburgh Limestone

The horizon of the Pittsburgh limestone is confined in its outcrops in Guernsey County to the higher hills and ridges in Oxford and Millwood townships and to southern Londonderry, eastern Wills, eastern Richland, southwestern Spencer, and southwestern Westland townships. The limestone is generally thin in these areas, consisting of nodules or a few thin discontinuous layers of limestone embedded in the Pittsburgh clay, and has trifling economic importance.

Fishpot Limestone

The Fishpot in Guernsey County is represented by thin limestone interbedded with calcareous shale occurring some 50 feet below the Meigs Creek coal and outcropping near the hilltops in southern Oxford, Millwood, southeastern Richland, and southwestern Spencer townships. For analyses of this limestone see pages of this report dealing with the Fishpot member in Muskingum, Noble, and Belmont counties.

HARRISON COUNTY

General Considerations

The bedrocks which reach the surface in Harrison County belong to that part of the stratigraphic section which has for its inferior limit the Middle Kittanning coal and for its upper boundary the Waynesburg A coal. The series exposed includes, therefore, both the Conemaugh and the Monongahela series, the lower 40 feet of the Washington series, and the upper 100 feet or so of the Allegheny series. As a result of the regional slope of the strata in a southeastern direction and of prolonged stream erosion which has dissected the land surface, exposures of the Allegheny series are confined to the lower slopes of the deep valleys along the western border of the county whereas strata of Monongahela and Permian ages form the high hills and ridges in the southeastern third of the county and are the sole beds exposed in the southern part of Short Creek Township and the eastern part of Athens Township. The total thickness of the sedimentary series reaching the surface in Harrison County is approximately 800 feet.

The various strata exposed in Harrison County consist for the most part of numerous beds of sandstone and shale, coal beds of minable thickness found only in the Allegheny and Monongahela series, and many limestone members, the thickest and best developed occurring in the Monongahela series. A generalized section of the beds outcropping in Harrison County, derived in part from unpublished field notes of George White, showing the succession, character, and average thickness of the different members, is as follows [1]:

Generalized Section of Bedrocks Outcropping in Harrison County

	Ft.	In.
Permian system		
Washington series		
Coal, Waynesburg A	2	0
Limestone, bluish gray, local, Mount Morris	5	0
Sandstone, generally with a thin shale bed at base, Waynesburg	33	0
Pennsylvanian system		
Monongahela series		
Coal, with one or more partings, Waynesburg or No. 11	2	8

[1] *Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17., pp 187-188, 1912.*

Shale, gray, arenaceous	14	0
Coal, very local, Little Waynesburg	-	6
Shale, gray, arenaceous	15	6
Coal, thin, generally present, Uniontown	-	10
Shale, calcareous to arenaceous, with occasional thin sandstone	24	2
Limestone, gray to bluish gray, somewhat marly, interbedded with calcareous shale, Arnoldsburg	16	2
Shale, light above green, Fulton	1	5
Limestone, gray to buff, often shaly, in places nodular and in layers with shale, Benwood	20	0
Shale, gray, arenaceous, and thin sandstone, Sewickley sandstone horizon	23	1
Shale, black, carbonaceous	-	11
Shale, gray	1	4
Coal, with one or more partings, Meigs Creek or No. 9	3	0
Shale, gray, arenaceous	13	0
Coal, shaly, and black coaly shale, Fishpot	-	7
Shale, arenaceous, with occasional thin sandstone	21	3
Limestone, gray to bluish gray, dense, thick to thin bedded, layers often separated by thin shale, Fishpot	18	0
Shale, gray, calcareous to arenaceous	16	5
Coal, somewhat shaly, and carbonaceous shale, Redstone or No. 8a	1	2
Limestone, gray to bluish gray, dense, interstratified with thin calcareous shale	10	2
Shale, arenaceous, with local deposits of sandstone, Pittsburgh sandstone horizon	8	0
Pittsburgh Or No. 8: Coal, bony, and black shale	1	0
Pittsburgh Or No. 8: Shale	1	0
Pittsburgh Or No. 8: Coal, with two or more thin partings	4	6
Conemaugh series		
Clay, gray	4	0
Limestone, gray, Pittsburgh	3	0
Shale, sandy in places	18	0
Limestone layers interlain with clay	8	0
Clay with nodular limestone	30	0
Shale	20	0
Limestone, buff, intermixed with lumps of white, Summerfield	2	0
Clay shale with nodular limestone, red in some localities, and with concretions of hematite	40	0
Shale, sandy	23	0

Sandstone, varying from shaly to coarse-grained, Morgantown	12	0
Limestone, fossiliferous, a rusty-gray rock; missing in many localities owing to replacement by overlying sandstone, Skelley	-	10
Coal streak, missing in many localities, Duquesne	-	-
Shale, red, varying to shaly sandstone	23	0
Limestone, fossiliferous, missing in many localities and conglomeratic in others, Ames	3	0
Shale, sandy	11	0
Coal, missing here and there, Harlem	1	0
Shale	26	0
Coal, thin, Barton	-	-
Clay, red in places, interlain with several layers of gray fossiliferous limestone, Ewing limestone horizon	11	0
Shale, sandy, varying to shaly sandstone	51	0
Limestone, fossiliferous, a very impure dark rock, having much pyrite under cover, Portersville	-	10
Coal, wanting in places, Anderson	1	6
Shale with limestone pellets	18	0
Limestone, yellowish, nodular in places, fossiliferous; a limestone conglomerate in a few places, Cambridge	1	3
Coal, thin in most localities, Wilgus	-	-
Sandstone, a massive coarse-grained rock in the southwestern part of the county, Buffalo	39	0
Shale, calcareous, carbonaceous, fossiliferous, with black nodular limestone embedded in it at a few places, Brush Creek beds	3	0
Sandstone, shaly	28	0
Clay, with a layer of limestone near the top	9	0
Sandstone, varying from shaly to massive	28	0
Coal, thin, Mahoning	-	-
Clay	7	0
Sandstone, varying from shaly to massive, Mahoning	31	0
Allegheny series		
Coal, good, Upper Freeport or No. 7	2	0
Sandstone, shale and covered	39	0
Coal, thin, Lower Freeport	1	3
Sandstone, shale, and covered	70	0
Coal good, Middle Kittanning	3	6

The rock series exposed in this county is not especially rich in limestone beds of good thickness and high purity. The limestone members of Conemaugh series as represented in this area are generally thin, discontinuous on the outcrop, and impure in character. The Ames limestone, the best developed of this group, locally occurs in sufficient thickness and purity to be utilized on a small scale for road stone and to a less extent for agricultural lime. Of the limestones of the

Monongahela, chief importance rests in the Redstone and Fishpot members. Their distribution includes many of the high ridges in German, Green, Short Creek, Athens, Cadiz, and Archer townships. Quarries have operated in Green, Short Creek, and Cadiz townships for the production chiefly of crushed stone for road construction and repair in the county.

No limestones of inviting proportions are known to occur in the Pennsylvanian series below drainage in Harrison County. The Maxville limestone, which in a few areas on the outcrop in Ohio is found at the base of this series and which is known as the Big Lime to the Berea sand driller of eastern Ohio, is generally wanting in records of wells sunk in Harrison County. Below the horizon of the Maxville, shales and sandstones extend downward for 3,000 feet or more below the surface, excluding all possibility of deep shaft mining of limestone within the limits of this county.

Brush Creek Member

The Brush Creek member in Harrison County consists of a few feet of dark carbonaceous fossiliferous shale, with only occasional boulder-like masses of dark limestone embedded in it. The position of the member is approximately 100 feet above the Upper Freeport coal and its distribution is confined chiefly to the western tier of townships in the county. It has trifling economic importance for its limestone content.

Cambridge Limestone

Along the valleys of Conotton Creek, Little Stillwater Creek, and Stillwater Creek, in western Harrison County, the Cambridge is a rusty, ferruginous, somewhat nodular limestone, generally measuring less than one foot in thickness and, therefore, possessing trifling economic possibilities. Locally its horizon is occupied by heavy-bedded sandstone. The position of the limestone is generally about 40 feet above the Brush Creek shale and about 145 feet above the Upper Freeport coal.

Portersville Member

The Portersville is of interest chiefly as a persistent stratigraphic unit rather than for its economic possibilities. In Harrison County this member consists of a few inches of dark fossiliferous shale with occasional limestone nodules occurring close above the Anderson coal and some 20 feet above the Cambridge limestone.

Ewing Limestone

The Ewing limestone, consisting for the most part of small nodules and thin, lens-like layers of fresh water limestone embedded in calcareous clays and clay shales underlying the Barlow coal, is persistent on the outcrop in Harrison County, but it is generally lacking in sufficient volume to warrant economic enterprise. The position of the limestone is approximately 50 feet below the Ames, the best bench for reference in this area. Outcrops are present in every township with the exception of German, Green, Short Creek, Athens, and Cadiz, located in the southeastern part.

Ames Limestone

The Ames limestone, which is generally a gray to greenish gray crystalline rock containing many fossil fragments, is widely distributed on the outcrop in Harrison County but locally is replaced by sandstone. The limestone ranges in altitude along the northern border from 1,245 feet in Section 9, Monroe Township, to 1,120 feet in Section 8, Rumley Township, and in the southwestern part from 1,200 feet in Section 4, Washington Township, to 990 feet in Section 35, Moorefield Township. Over large areas in North and Nottingham townships and over many small areas elsewhere in the western part of the county the Ames has been replaced by Morgantown sandstone. Where present the thickness of the limestone varies from a few inches to about 5 feet but the usual measurements are from 1 to 2 feet. Loose blocks of Ames limestone along the outcrop have been gathered by farmers in several localities and have been pulverized for agricultural lime. Quarries have operated in this limestone on the Vickers property in Section 26, Franklin Township, and on Birny property in Section 1, Franklin Township, for the production of crushed stone for road construction.

The Ames limestone has been quarried and pulverized on a small scale for home consumption on the J. B. Gladman Heirs property located in the south central part of Section 32, Franklin Township. The limestone is well exposed near the head of the ravine just back of the Gladman house where the following measurements were secured.

		Ft.	In.
Covered		-	-
Limestone, dark gray to light brownish gray, one ledge	Ames	1	10
Limestone, gray to light brownish gray, hard, one ledge	Ames	3	6
Base of exposure.			

A sample of the 5 feet 4 inches of limestone exposed here was cut by R. E. Lamborn on August 22, 1944, for chemical analysis.

Sample No. 438

Chemical analysis of Ames limestone from exposures on the J. B. Gladman Heirs property, Section 32, Franklin Township, Harrison County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	6.84
Alumina, Al_2O_3	1.51
Ferric oxide, Fe_2O_3	0.24
Ferrous oxide, FeO	0.78
Iron disulphide, FeS_2	0.21
Magnesium oxide, MgO	0.82
Calcium oxide, CaO	48.80
Sodium oxide, Na_2O	0.10
Potassium oxide, K_2O	0.29
Water, hydroscopic, H_2O-	0.19
Water, combined, H_2O+	0.62
Carbon dioxide, CO_2	38.84
Titanium dioxide, TiO_2	0.05
Phosphorus pentoxide, P_2O_5	0.18
Sulphur trioxide, SO_3	0.12
Manganous oxide, MnO	0.25
Total	99.84

The per cent of each of the mineral components in Sample No. 438 as determined by calculation (Lamborn) from the chemical analysis is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	3.71
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.27
Silica, SiO_2	5.06
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.28
Ferrous carbonate, $FeO.CO_2$	1.26
Iron disulphide, FeS_2	0.21
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO.P_2O_5$	0.39
Calcium sulphate, $CaO.SO_3$	0.20
Calcium carbonate, $CaO.CO_2$	86.57
Magnesium carbonate, $MgO.CO_2$	1.71
Manganese carbonate, $MnO.CO_2$	0.41
Water, hydroscopic, H_2O-	0.19
Unbalanced components (excess CO_2, H_2O)	-0.47
Total	99.84

Skelley Limestone

Concerning the occurrence of this member in Harrison County Condit states:[1] "The Skelley, lying a few feet above the Ames, is seldom more than rusty, very impure limestone one foot thick at most." Its economic importance as a source for high-grade limestone or for crushed stone products is therefore negligible.

Summerfield Limestone

The Summerfield limestone was first named by Condit for its occurrence near Summerfield, Noble County.[2] It occurs in good development and purity in eastern Noble and southeastern Guernsey counties but it tends to thin and become less constant in its occurrence along the outcrop to the northeast. In the southeastern third of Harrison County the horizon of this member is in places occupied by red or gray sandy shale. Where present the limestone is generally buff to white in color with a thickness varying from a few inches to 2 or 3 feet. For analyses of Summerfield limestone see pages of this report dealing with that member in Guernsey and Noble counties.

Pittsburgh Limestone

The Pittsburgh limestone is confined in its distribution in Harrison County to the southeastern portion including parts of Moorefield, Nottingham, Athens, Cadiz, Archer, Short Creek, Green, and German townships. Its stratigraphic position is either immediately below the well known Pittsburgh coal or separated from that member by a thin bed of calcareous shale. The limestone member may consist of a single bed or stratum or of several layers with thin shale partings between them. The thickness of the limestone and interstratified shale varies from 1 to 20 feet but measurements of 2 to 7 feet are most common. The stone may be thin and nodular to thick-bedded and is generally a gray to bluish gray color. Clay and siliceous and ferruginous impurities are generally present in relatively small but varying amounts. The Pittsburgh is not an important source of limestone for economic use in eastern Ohio due in part to the presence of other limestones occur-

[1] *Condit, D. D., op. cit., p. 189.*

[2] *Condit, D. D., op. cit., p. 23.*

ring close above the Pittsburgh coal which are widespread within its area of outcrop.

In German Township the Pittsburgh limestone was formerly quarried by Oliver Monaco about 2 miles east of Germano in the northern part of Section 14. Crushed stone for road purposes and pulverized lime for agricultural use are reported to have been the chief products. In 1948 a core hole was drilled through the Pittsburgh limestone on the Monaco property near the north central edge of Section 14 and the core through the limestone was submitted by Mr. Monaco and Mr. Stanchaina for examination and analysis. A description of the limestone is given below:

		Ft.	In.
Base of Pittsburgh or No. 8 coal			
Limestone, light brown to chocolate brown, dense, tough, breaks with stony irregular surface, sampled	Pittsburgh	3	7
Limestone, light to dark brown, dense, brecciated, light breccia embedded in dark ground mass, sampled	Pittsburgh	-	11
Limestone, gray to gray brown, dense, sampled	Pittsburgh	-	11
Shale, dark gray, calcareous, soft and argillaceous at top becoming sandy and micaceous downward, not sampled	Pittsburgh	1	0
Limestone, brown to gray brown, dense, some thin partings of gray shale, sampled	Pittsburgh	1	5
Shale, light to dark gray, soft, argillaceous, calcareous		1	0
Sandstone, gray, calcareous, micaceous		2	11
Shale, mottled, calcareous, argillaceous		1	10
Shale, gray to gray black, micaceous		6	7

The core through the limestone having a total length of 6 feet 10 inches was analyzed and yielded the following results.

Sample No. 406

Chemical analysis of Pittsburgh limestone from core drilled on Oliver Monaco property, Section 14, German Township, Harrison County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	5.51

Alumina, Al_2O_3	1.26
Ferric oxide, Fe_2O_3	0.07
Ferrous oxide, FeO	1.29
Iron disulphide, FeS_2	0.28
Magnesium oxide, MgO	0.81
Calcium oxide, CaO	49.39
Sodium oxide, Na_2O	0.07
Potassium oxide, K_2O	0.17
Water, hydroscopic, H_2O-	0.04
Water, combined, H_2O+	0.58
Carbon dioxide, CO_2	40.27
Titanium dioxide, TiO_2	0.05
Phosphorus pentoxide, P_2O_5	0.09
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.30
Total	100.22

The per cent of each of the mineral components in the sample as computed (Lamborn) from the chemical analysis is shown below:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	2.30
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.92
Silica, SiO_2	4.03
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.08
Ferrous carbonate, $FeO.CO_2$	2.08
Iron disulphide, FeS_2	0.28
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO.P_2O_5$	0.20
Calcium sulphate, $CaO.SO_3$	0.07
Calcium carbonate, $CaO.CO_2$	87.91
Magnesium carbonate, $MgO.CO_2$	1.69
Manganese carbonate, $MnO.CO_2$	0.48
Water, hydroscopic, H_2O-	0.04
Unbalanced components (deficiency CO_2, H_2O)	+0.09
Total	100.22

Redstone Limestone

The Redstone limestone is widely distributed on the outcrop in southeastern Harrison County being present in some degree of development in Nottingham, Stock, Archer, German, Green, Short Creek, Athens, Cadiz, and Moorefield townships. The thickest development, however, is found in German, Green, and Short Creek townships where in places the limestone fills almost the entire interval between the Pittsburgh and Redstone coals. The limestone tends to thin to the west from this area and in parts of Cadiz, Moorefield, and Nottingham townships it is replaced with sandy shale and sandstone. In typical development the Redstone member consists of several layers of gray to bluish gray, hard, dense-textured, compact stone, separated by bluish gray calcareous shale partings. In places where the member is thin the limestone possesses a somewhat bouldery character. The thickness of the Redstone varies from a foot or so to a maximum of over 30 feet. The average thickness in this county, however, is close to 10 feet. Quarries have operated in Green, Cadiz, and Short Creek townships for the production chiefly of road stone and to a less extent for agricultural lime.

Harrison County operates a quarry in the Redstone limestone on the J. B. Mallarnee property in the northwest quarter of Section 3, Cadiz Township. The quarry is located at the head of a small ravine and just north of the Moraville-Cadiz road. The exposures in this locality are described as follows:

		Ft.	In.
Coal, weathered, Redstone or 8a		1	8
Clay shale, bluish gray, soft		5	2
Limestone, dark bluish gray, hard	Redstone	2	6
Limestone, bluish gray, softer	Redstone	1	0
Limestone, bluish gray, hard	Redstone	7	8
Shale, bluish gray, calcareous, not sampled	Redstone	-	4
Limestone, light bluish gray, hard, flint-like fracture	Redstone	1	4
Shale, bluish gray, calcareous, not sampled	Redstone	-	6
Limestone, bluish gray, dense texture, compact	Redstone	2	10
Covered interval		11	11
Coal	Pittsburgh or No. 8	1	0
Shale, black	Pittsburgh or No. 8	-	3
Coal	Pittsburgh or No. 8	1	10
Clay shale parting	Pittsburgh or No. 8	-	1/4
Coal	Pittsburgh or No. 8	-	3
Clay shale	Pittsburgh or No. 8	-	1/2
Coal	Pittsburgh or No. 8	1	11
Clay, dark		-	10

The limestone beds of the Redstone member exposed in this quarry were sampled for chemical analysis on July 29, 1941, by R. E. Lamborn.

Sample No. 364

Chemical analysis of Redstone limestone from County quarry, Section 3, Cadiz Township, Harrison County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	14.63
Alumina, Al_2O_3	4.20
Ferrous carbonate, Fe_2O_3	0.03
Ferrous oxide, FeO	0.95
Iron disulphide, FeS_2	0.01
Magnesium oxide, MgO	1.25
Calcium oxide, CaO	41.40
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.16
Potassium oxide, K_2O	0.64
Water, hydroscopic, H_2O-	0.93
Water, combined, H_2O+	0.95
Carbon dioxide, CO_2	34.29
Titanium dioxide, TiO_2	0.22

Phosphorus pentoxide, P_2O_5	0.18
Sulphur trioxide, SO_3	0.06
Manganous oxide, MnO	0.11
Carbon, organic, C	0.02
Hydrogen, organic, H	--
Total	100.03

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	7.38
Silicates $Al_2O_3.2SiO_2.2H_2O$	3.37
Silica, SiO_2	9.69
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.03
Ferrous carbonate, $FeO.CO_2$	1.53
Iron disulphide, FeS_2	0.01
Titanium dioxide, TiO_2	0.22
Calcium phosphate, $3CaO.P_2O_5$	0.39
Calcium sulphate, $CaO.SO_3$	0.10
Calcium carbonate, $CaO.CO_2$	73.44
Magnesium carbonate, $MgO.CO_2$	2.61
Manganese carbonate, $MnO.CO_2$	0.18
Water, hydroscopic, H_2O-	0.93
Organic matter	0.02
Unbalanced components (deficiency CO_2, H_2O)	+0.13
Total	100.03

The Redstone limestone has been pulverized and marketed for agricultural use by Mr. Boyd Wallace at his quarry located just north of highway in the central part of Section 25, Green Township, five-eighths of a mile south of west of Greenough. The exposures in the quarry are described below:

		Ft.	In.
Shale, weathered		10	0
Coal and black shale, Redstone or No. 8		2	3
Clay shale, calcareous		1	0
Shale with nodules of limestone		1	0
Limestone, bluish gray, sampled	Redstone	1	0
Shale, calcareous, not sampled	Redstone	-	6
Limestone, bluish gray, sampled	Redstone	-	10
Shale, calcareous, not sampled	Redstone	-	2
Limestone, bluish gray, sampled	Redstone	1	6
Shale, calcareous, not sampled	Redstone	-	2
Limestone, light bluish gray, breaks with flint-like fracture, sampled	Redstone	5	0
Shale, calcareous, not sampled	Redstone	-	1
Limestone, dark bluish gray, sampled	Redstone	1	2

Limestone, dark bluish gray, sampled	Redstone (cont.)	1	8
Clay, with nodules and boulders of dark limestone, not sampled		3	6
Bottom of quarry.			

The limestone layers described above having a total thickness of about 11 feet were sampled by R. E. Lamborn on July 29, 1941, for chemical analysis.

Sample No. 363

Chemical analysis of Redstone limestone from quarry of Mr. Boyd Wallace, Section 25, Green Township, Harrison County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	11.28
Alumina, Al_2O_3	3.44
Ferric oxide, Fe_2O_3	0.06
Ferrous oxide, FeO	1.88
Iron disulphide, FeS_2	0.07
Magnesium oxide, MgO	5.45
Calcium oxide, CaO	38.30
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.11
Potassium oxide, K_2O	0.49
Water, hydroscopic, H_2O-	0.72
Water, combined, H_2O+	0.65
Carbon dioxide, CO_2	36.95
Titanium dioxide, TiO_2	0.15
Phosphorus pentoxide, P_2O_5	0.18
Sulphur trioxide, SO_3	0.15
Manganous oxide, MnO	0.13
Carbon, organic C	0.01
Hydrogen, organic, H	--
Total	100.02

The per cent of each of the compounds probably present in Sample No. 363 has been computed (Lamborn) from the chemical analysis.

Silicates	$(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	5.50
	$Al_2O_3.2SiO_2.2H_2O$	3.31
Silica, SiO_2		7.23
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$		0.07
Ferrous carbonate, $FeO.CO_2$		3.03
Iron disulphide, FeS_2		0.07
Titanium dioxide, TiO_2		0.15
Calcium phosphate, $3CaO.P_2O_5$		0.39
Calcium sulphate, $CaO.SO_3$		0.25
Calcium carbonate, $CaO.CO_2$		67.79
Magnesium carbonate, $MgO.CO_2$		11.39
Manganese carbonate, $MnO.CO_2$		0.21
Water, hydroscopic, H_2O-		0.72
Organic matter		0.01
Unbalanced components (excess CO_2, H_2O)		-0.10
Total		100.02

Fishpot Limestone

In Harrison County the Fishpot limestone occurs in good development on the outcrop in Short Creek and eastern Athens townships. It is thin in northwestern German Township, whereas in Archer, southern Green, Cadiz, western Athens, Moorefield, and Nottingham townships its horizon is largely occupied with arenaceous shale and sandstone. The thickness of the limestone in eastern Athens and Short Creek townships varies from 5 to 35 feet or more but the average is about 18 feet. The limestone is typical for the member, being a gray to bluish gray, dense-textured rock occurring in layers separated by bedding planes only or by calcareous shale partings. Argillaceous and siliceous impurities usually occur in appreciable amounts reducing the carbonate content of the stone.

At a strip mine in the Pittsburgh coal operated by the Hanna Coal Company and located in the south central part of Section 25, Short Creek Township, the lower 75 feet of the Monongahela series is well shown. Here the Fishpot limestone occupies nearly the entire interval between the Redstone and Fishpot coals. A detailed description of the exposures as recorded by George White during the summer of 1944 is as follows:

		Ft.	In.
Sandstone, shaly		4	0
Shale, siliceous, ferruginous		4	0
Shale, carbonaceous, Fishpot coal horizon		-	6
Limestone, weathered	Fishpot	5	7
Shale, greenish gray, calcareous	Fishpot	1	8
Shale, siliceous to sandy	Fishpot	14	10
Shale, gray, clay-like, somewhat calcareous	Fishpot	3	3
Limestone, gray, flinty fracture, sampled	Fishpot	-	4
Limestone, gray, oolitic appearing, sampled	Fishpot	-	6
Limestone, dark gray, irregularly shaly, sampled	Fishpot	-	5
Limestone, drab gray, very dense, conchoidal fracture, sampled	Fishpot	-	7
Limestone, drab gray, fine-banded, oolitic streaks, sampled	Fishpot	-	8
Limestone, blue gray, weathered, shaly, fossiliferous, sampled	Fishpot	1	0

Limestone, bluish gray, hard, finely crystalline, sampled	Fishpot (cont.)	1	3
Limestone, dark gray, very fine-grained, brittle, conchoidal fracture, sampled	Fishpot (cont.)	2	6
Limestone, dark blue gray, argillaceous, flint-like fracture, sampled	Fishpot (cont.)	1	8
Limestone, blue gray, somewhat shaly, with plant fragments, sampled	Fishpot (cont.)	-	8
Limestone, light gray, fine-grained, sampled	Fishpot (cont.)	-	4
Limestone, light gray, very fine-grained, flint-like fracture, sampled	Fishpot (cont.)	-	3
Limestone, blue gray, very shaly, sampled	Fishpot (cont.)	-	2
Limestone, dove gray, dense, very hard, sampled	Fishpot (cont.)	4	3
Shale, dark blue gray, calcareous, not sampled	Fishpot (cont.)	-	4
Limestone, gray, fine-grained, dense, sampled	Fishpot (cont.)	1	8
Shale, gray blue, calcareous, not sampled	Fishpot (cont.)	-	3
Limestone, gray, sampled	Fishpot (cont.)	-	6
Shale, gray, calcareous, not sampled	Fishpot (cont.)	-	2
Limestone, light gray, dense, hard, sampled	Fishpot (cont.)	2	4
Limestone, blue gray, not sampled	Fishpot (cont.)	-	6
Clay shale, gray, calcareous		2	6
Shale, black, carbonaceous, hard	Redstone or No. 8a	-	5
Coal, bony	Redstone or No. 8a	-	2
Coal, bright, blocky	Redstone or No. 8a	-	5

			Feet	Inches
Shale, carbonaceous to bony, hard, fossiliferous	Redstone or No. 8a (cont.)	....	-	6
Limestone, dark gray, argillaceous		....	-	4
Shale, blue gray, calcareous		....	-	8
Limestone, gray blue, dense, flint-like fracture		....	13	0
Shale and covered			4	5
Coal, shaly to bony, hard	Pittsburgh or No. 8	....	-	2
Coal, bright, blocky		....	2	0
Shale, carbonaceous		....	-	3/4
Coal, with thin shale layers		....	-	3
Shale, carbonaceous		....	-	1/2
Coal, bright, blocky		....	1	2
Clay shale, gray		....	-	3/8
Coal, bright, blocky		....	-	11
Clay shale, carbonaceous			-	3

The beds of Fishpot limestone, indicated on the above section, having a total thickness of 18 feet 9 inches, were sampled by George White in the summer of 1944 and the sample was submitted for chemical analysis.

Sample No. 440

Chemical analysis of Fishpot limestone from pit of Hanna Coal Company, Section 25, Short Creek Township, Harrison County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	14.00
Alumina, Al_2O_3	3.19
Ferric oxide, Fe_2O_3	0.93
Ferrous oxide, FeO	1.48
Iron disulphide, FeS_2	0.21
Magnesium oxide, MgO	7.67
Calcium oxide, CaO	34.25
Sodium oxide, Na_2O	0.16
Potassium oxide, K_2O	0.76
Water, hydroscopic, H_2O-	0.40
Water, combined, H_2O+	1.28
Carbon dioxide, CO_2	35.00
Titanium dioxide, TiO_2	0.13
Phosphorus pentoxide, P_2O_5	0.07
Sulphur trioxide, SO_3	0.08
Manganous oxide, MnO	0.10
Total	99.71

The per cent of each of the various mineral constituents in sample No. 440 as determined by calculation (Lamborn) from the chemical analysis is given below:

Silica and hydrated aluminum silicates of sodium and potassium	19.23
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	1.09
Ferrous carbonate, $FeO.CO_2$	2.39
Iron disulphide, FeS_2	0.21
Titanium dioxide, TiO_2	0.13
Calcium phosphate, $3CaO.P_2O_5$	0.15
Calcium sulphate, $CaO.SO_3$	0.14
Calcium carbonate, $CaO.CO_2$	60.88
Magnesium carbonate, $MgO.CO_2$	16.03
Manganese carbonate, $MnO.CO_2$	0.16
Water, hydroscopic, H_2O-	0.40
Unbalanced components (excess CO_2)	-1.10
Total	99.71

Benwood Limestone

The position of the Benwood limestone in the rock column, as indicated in the generalized section, is above the Meigs Creek coal and close below the Fulton Green shale. Limestone belonging to this member in Harrison County is confined in outcrops chiefly to the high hills and ridges in Short Creek, eastern Athens, southeastern Cadiz, and southern Green townships. The thickness of the limestone and interstratified shale varies from 5 to 50 feet, but the average is close to 20 feet. The member is probably best developed in southeastern Short Creek and southeastern Green townships where it consists of bluish gray to buff dense argillaceous limestone interstratified with shale. For an analysis of the Benwood limestone see pages of this report describing that member in Belmont County.

Arnoldsburg - Uniontown Limestone

The stratigraphic position of this limestone is in the interval between the Fulton Green shale below and the Uniontown coal above. Owing to the general absence of the Arnoldsburg sandstone the two limestone members cannot be satisfactorily separated in this county. The most persistent deposits of limestone are found close above the Fulton Green shale and therefore correspond in position to the Arnoldsburg member.

The distribution of the Arnoldsburg-Uniontown limestone in Harrison County is confined to the high ridges in eastern Green, southeastern Short Creek, and southeastern Cadiz townships. In field sections taken by George White the thickness of the limestone and interstratified shale varies from about 7 to 35 feet but the thickest development is found in eastern Green and southeastern Short Creek townships. This member is not known to be utilized for economic purposes in Harrison County.

Mount Morris Limestone

The hills of southeastern Harrison County are not high enough to provide a large area distribution of Mount Morris limestone. It is reported to outcrop at only one locality, namely in Section 16, Short Creek Township, where it is bluish gray in color with a thickness of about 11 feet.

HOCKING COUNTY

General Considerations

The bedrocks which reach the surface in Hocking County belong to the Mississippian and Pennsylvanian systems and represent a vertical section of strata approximating 1,000 feet in thickness. The beds of Mississippian age outcrop over an area of about 209 square miles which includes, in general, the western half of the county. They consist for the most part of sandstones, shales, and conglomerates belonging to the Cuyahoga and Logan formations, capped in one or two localities along the outcrop with thin remnants of Maxville limestone. The outcrops of Pennsylvanian strata are confined chiefly to Washington, Starr, Falls, Green, Ward, Falls Gore, and Marion townships in the eastern half of the county although small outliers cap the higher ridges in Laurel, Benton, and southeastern Salt Creek townships. The part outcropping includes the Pottsville and Allegheny series and the lower 100 feet of the Conemaugh series. Like the Mississippian the Pennsylvanian is composed chiefly of sandstones and shales. The coals, clays, limestones, and iron ore constitute but a small fraction of this group. The chief limestone-bearing units which have been recognized in the rock series exposed in Hocking County are in descending order as follows:

Cambridge limestone
Brush Creek member
Vanport member
Putnam Hill member
Upper Mercer member
Lower Mercer member
Boggs member
Maxville formation

The limestone beds of the Pennsylvanian are poorly developed in Hocking County, being in general discontinuous on the outcrop, inconstant in character, and invariably thin. Quarries have operated along the outcrop of the Maxville limestone near Logan.

The clastic beds exposed in the western half of Hocking County are directly underlain by a thick series of shales with one thin sandstone, which extend down to the top of the Big Lime. In wells drilled for oil and gas the Big Lime is encountered at depths below sea level ranging from approximately 100 feet in northwestern Perry Township to about 1,500 feet in the southeastern part of Starr Township.

Maxville Limestone

The Maxville limestone is generally wanting in Hocking County as this formation was almost completely removed by erosion before the deposition of the superjacent beds. Only one deposit of Maxville limestone has been noted on the outcrop in Hocking County. This is located just east of Smith Chapel in Section 28, Green Township. Here the limestone has been quarried for furnace flux and later for road stone. The formation consists of bluish gray limestone, somewhat argillaceous and impure in composition, separated by thin beds of calcareous shale, having a total thickness close to 10 feet.[1]

Records of wells drilled in the eastern part of Hocking County indicate the general absence of this formation below drainage. Fifty feet of limestone on the

[1] *Morse, W. C. The Maxville limestone: Geol. Survey Ohio Bull. 13, pp. 78-79, 1910.*

Maxville horizon, however, has been reported in borings on the S. Scott Heirs property in Section 26, Starr Township.

Boggs Member

The Boggs member in this county consists of thin nodular ore, flint and ore, or fossiliferous shale lying close above the Lower Mercer coal and 20 to 35 feet below the Lower Mercer limestone. It has no value for its lime content.

Lower Mercer Limestone

The Lower Mercer limestone member may consist in this county of thin limestone often nodular in character, of thin limestone either overlain or underlain with fossiliferous shale, or of fossiliferous shale alone. The thickness of the member varies from 2 inches to 4 feet 6 inches. An average of 46 measurements taken in the field by Wilber Stout is 1 foot 3 inches. It is persistent along the outcrop line which passes through Marion, Falls, Falls Gore, Green, Ward, Benton, Washington, and Starr townships but the thickest and purest known deposits of limestone on the horizon occur in the vicinity of Union Furnace in Starr Township.

The Middle Mercer clay which closely underlies the Lower Mercer limestone was formerly mined at Union Furnace and utilized for the production of building brick. The limestone is exposed in good development above the old workings located on the north side of the diagonal road one-fourth mile east of its junction with State Route 328 in the southwest quarter of Section 23, Starr Township. A description of the limestone exposed at this locality is as follows:

		Ft.	In.
Limestone, dark bluish gray, very fossiliferous	Lower Mercer	1	6
Limestone, dark bluish gray, very fossiliferous		2	4

The underlying thin shale and coal were not clearly exposed at this outcrop. The limestone as described above having a total thickness of 3 feet 10 inches was sampled on August 12, 1943, by R. E. Lamborn for chemical analysis.

Sample No. 415

Chemical analysis of Lower Mercer limestone from outcrop near Union Furnace, Section 23, Starr Township, Hocking County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	55.18
Alumina, Al_2O_3	5.73
Ferric oxide, Fe_2O_3	0.45
Ferrous oxide, FeO	1.08
Iron disulphide, FeS_2	0.88
Magnesium oxide, MgO	0.73
Calcium oxide, CaO	17.74
Sodium oxide, Na_2O	0.20
Potassium oxide, K_2O	1.14

Water, hydroscopic, H_2O-	0.30
Water, combined, H_2O+	1.76
Carbon dioxide, CO_2	14.06
Titanium dioxide, TiO_2	0.23
Phosphorus pentoxide, P_2O_5	0.20
Sulphur trioxide, SO_3	0.16
Manganous oxide, MnO	0.08
Total	99.92

The per cent of each of the mineral components present in Sample No. 415 as calculated (Lamborn) from the analysis is given below.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	12.11
Silicates $Al_2O_3.2SiO_2.2H_2O$	2.64
Silica, SiO_2	48.43
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.53
Ferrous carbonate, $FeO.CO_2$	1.74
Iron disulphide, FeS_2	0.88
Titanium dioxide, TiO_2	0.23
Calcium phosphate, $3CaO.P_2O_5$	0.44
Calcium sulphate, $CaO.SO_3$	0.27
Calcium carbonate, $CaO.CO_2$	31.04
Magnesium carbonate, $MgO.CO_2$	1.52
Manganese carbonate, MnO.CO	0.13
Water, hydroscopic, H_2O-	0.30
Unbalanced components (excess CO_2, H_2O)	-0.34
Total	99.92

Upper Mercer Limestone

The Upper Mercer member is represented on the outcrop in this county by thin discontinuous deposits of either impure limestone, limestone and flint, flint, or fossiliferous shale. Recorded measurements of this member show variations in thickness ranging from a few inches to about 2 feet. Due to the low thickness and high siliceous character this member has trifling economic importance in Hocking County.

Putnam Hill Limestone

As the Putnam Hill member is either wanting or is represented in the county by thin fossiliferous shale with only an occasional thin layer of limestone measuring a few inches in thickness, it has no economic importance for its lime content.

Vanport Limestone

The Vanport limestone which is a well developed member in southern Vinton County and in Lawrence County is generally wanting on the outcrop in Hocking County. A few scattered deposits on this horizon have been recognized in Green, Washington, and Starr townships where the member is represented by flint or flinty limestone varying from a few inches to 1 foot in thickness.

Lower and Upper Freeport Limestones

The Lower and Upper Freeport limestones generally consist of thin layers or nodular masses of limestone occurring at the base of or embedded in the underclays of the Lower and Upper Freeport coals respectively. No unusual development of these limestone members is known to occur in Ward and Starr townships where outcrops are due.

Brush Creek Member

Outcrops of the Brush Creek limestone horizon are confined in its distribution in this county to the high hills and ridges in central and eastern Ward Township and possibly eastern Starr Township. According to Merrill, [1] the limestone phase of this member in Ward Township consists of a gray to brownish gray coarsely crystalline fossiliferous bed about 2 feet in thickness. It is not known to have been utilized in this area.

Cambridge Limestone

Nodules of gray fossiliferous limestone embedded in clay shale representing the Cambridge limestone have been recognized at a few localities near the hilltops in eastern Ward Township, [2] and similar occurrences are probable in eastern Starr Township. The limestone has no economic importance in this county.

HOLMES COUNTY

General Considerations

The bedrocks which are due to crop out at the surface in Holmes County comprise a series approximately 550 feet in thickness consisting of sandstone and shale beds of Mississippian age and many sandstones, shales, coals, clays, and limestone members of the Pottsville and Allegheny series of the Pennsylvanian system. The sandstones and shales of the Mississippian have a maximum thickness exposed in this county of approximately 250 feet. Their outcrops are confined chiefly to the lower slopes of the deep valleys in the western half of the county, including the Killbuck Valley in Killbuck, Hardy, and Prairie townships; the valleys of Doughty Creek and Martins Creek in Mechanic and Salt Creek townships; Wolf Creek in Killbuck and Richland townships; Black Creek in Killbuck, Richland, Knox, and southern Monroe townships; and Paint Creek in Prairie, Ripley, and northern Monroe townships. A large part of the outcrops along the Lake Fork Valley in Washington Township are of rocks of Mississippian age.

The clastic deposits of the Mississippian are overlain unconformably by the Pottsville series of the Pennsylvanian above which in conformable sequence is the Allegheny. Beds of Pennsylvanian age are due at or close to the surface along all the high ridges in the western half, comprise much of the section in the central portion, and make up the entire series exposed in the eastern tier of townships in this county. The bedrock surface in the northern half and along the western edge of the area is more or less obscured by deposits of glacial drift which constitute the southern border of the continental drift sheet. A generalized section of the bedded rocks exposed in Holmes County showing the succession of members and the character and thickness of each is essentially as follows: [3]

[1] *Merril, W. M., Geology of Green and Ward townships, Hocking County, Ohio: Unpublished Thesis for M.A. degree, Department of Geology, Ohio State University, 1948.*

[2] *Merrill, W. M., op. cit.*

[3] *The section of the Pennsylvanian series given here as well as much data in the following pages on Holmes County are from unpublished field notes and papers by Dr. George White.*

Generalized Section of Bedrocks Outcropping in Holmes County

	Ft.	In.
Pennsylvanian system		
Allegheny series		
Coal, locally present, Lower Freeport or No. 6a	1	1
Clay, plastic, siliceous, local	4	0
Shale, gray to buff, siliceous	49	8
Shale, carbonaceous, fossiliferous, Washingtonville	1	8
Coal, persistent, Middle Kittanning or No. 6	2	0
Clay, plastic, impure	3	10
Sandstone, often replaced by shale	36	5
Shale, carbonaceous, calcareous, and fossiliferous, locally present	1	1
Coal, persistent, Lower Kittanning or No. 5	2	1
Clay, plastic, fair quality	5	4
Shale, sandy	13	9
Limestone, greenish, ferruginous, rarely present, Vanport	1	3
Clay shale, gray to buff, with ore in nodules	16	0
Limestone, bluish gray, fossiliferous, very persistent, Putnam Hill	3	4 1/2
Clay shale	-	2 1/2
Coal, fair (Brookville or No. 4)	-	6
Clay shale, dark (Brookville or No. 4)	-	2
Coal, fair (Brookville or No. 4)	-	9
Pottsville series		
Clay, plastic, siliceous, fair quality	6	5
Shale and shaly sandstone	18	9
Coal, shaly, persistent, always thin, Tionesta or No. 3b	-	4 1/2
Clay, gray, plastic, siliceous	4	1
Shale, sandy	19	7
Limestone, dark blue, fossiliferous, often flinty, often wanting, Upper Mercer	1	11 1/2
Coal, poor (Bedford)	1	0
Clay shale (Bedford)	-	9
Coal, poor (Bedford)	1	4 1/2
Clay, plastic, siliceous, impure	3	0
Shale, sandy	5	11
Coal, very bony, and bone shale, locally present, Upper Mercer or No. 3a	1	3
Clay, plastic, siliceous, impure	1	6
Shale, sandy	12	2
Ore, shaly, fossiliferous, Lower Mercer	-	4
Limestone, blue, hard, fossiliferous, fairly persistent, Lower Mercer	2	10 1/2
Coal, very shaly, persistent, Middle Mercer	-	9
Clay, plastic, siliceous	4	3
Shale, sandy	3	1

Coal, locally present, Flint Ridge	-	7
Clay, plastic, siliceous	2	11
Shale	10	1
Ore, shaly, impure, generally wanting, Boggs	-	6
Coal, shaly, Lower Mercer or No. 3	1	5
Clay, plastic, siliceous	1	7
Shale	6	9
Ore, calcareous, generally wanting, Lowellville (Poverty Run)	2	1
Coal, generally wanting, Vandusen	-	8
Clay, plastic, siliceous	3	5
Shale	20	3
Coal, shaly, Bear Run	-	7
Clay, plastic	5	0
Sandstone and shale, sandstone locally well developed replacing overlying members below the Lower Mercer coal, Upper Massillon	9	1
Coal, fair, locally present, Quakertown or No. 2	1	7 1/2
Clay, plastic, sandy, impure	1	9
Shale, sandy	5	2
Ore, impure, sandy, with quartz pebbles generally present, Harrison	1	1
Mississippian system		
Sandstone and shale, maximum thickness exposed approximately	250	0

The limestones which reach the surface in Holmes County all belong to the Pennsylvanian system. The Maxville limestone which in normal succession caps the sandstones and shales of the Mississippian, and which has been quarried in Muskingum County and in other areas along the crop line in southern Ohio, is not present in the outcrop in this county, its absence being due to extended erosion preceding the deposition of superjacent beds. Of the Pennsylvanian limestones the Putnam Hill of lower Allegheny age is outstanding for its thickness, continuity, and general high quality. Quarries have operated along the outcrop of this member in Clark, Berlin, Hardy, Paint, Knox, and Richland townships for the production of road stone and agricultural lime.

The bedrocks which underlie the lowest strata exposed in Holmes County consist of sandstones and shales to a depth of several hundred feet. Wells drilled for oil and gas in the Clinton sand pass through these shales, reaching the Middle Devonian limestones (top of Big Lime of the Clinton sand driller) at depths below sea level ranging from 600 feet in the northwestern part of Washington Township to 1,700 feet in the southeastern part of Berlin Township.

Lowellville (Poverty Run) Member

The Lowellville member, which consists of thin impure limestone in Muskingum and Mahoning counties, is represented at only a few localities in Knox, Monroe, and Mechanic townships by thin iron ore and ferruginous shales.

Boggs Member

This member is represented in Holmes County by a few thin local deposits of iron ore and ferruginous shale occurring on an average about 22 feet below the Lower Mercer limestone.

Lower Mercer Limestone

The horizon of the Lower Mercer limestone is due at the surface in parts of every township in the county. Owing to the general presence of glacial drift, outcrops are rare in the northern part including Paint, Salt Creek, northern Berlin, Hardy, Prairie, Ripley, northern Monroe, and southeastern Washington townships. The thickness of the limestone varies from a few inches to 5 feet. The average of measurements along the outcrop as indicated in the general section is 2 feet 10 1/2 inches. Areas of better-than-average development of Lower Mercer limestone in this county include some of the high ridges in Knox and northern Richland townships, parts of eastern Berlin Township, and the valley of Walnut Creek in southeastern Walnut Creek Township. Owing to the wide distribution of the thicker and purer Putnam Hill limestone, which occurs on an average some 80 feet higher in the section, the Lower Mercer has been little utilized in Holmes County.

Upper Mercer Limestone

The Upper Mercer limestone is represented in Holmes County by thin discontinuous deposits of black impure limestone, flinty limestone, or black flint which occurs on an average about 30 feet above the Lower Mercer limestone. In many places this member is wanting.

Putnam Hill Limestone

In vertical scale the Putnam Hill limestone is found close above the Brookville or No. 4 coal and about 80 feet above the Lower Mercer limestone previously described. Its outcrops in Holmes County are found in every township except Washington in the northwestern corner. In eastern Knox, eastern Richland, southwestern Ripley, northeastern Prairie, northern Salt Creek, and northern Paint townships outcrops of this limestone occur along the upper slopes of the highest ridges. Owing to the regional dip, the altitude of the outcrops tends to decrease to the southeast and in Clark Township this limestone is found close above drainage along the valley of Sugar Creek. The thickness of the Putnam Hill limestone on the outcrop in Holmes County varies from a few inches to a maximum of about 7 feet, but averages about 3 feet 4 inches. The fields of best known development in this county include eastern Hardy, northeastern Berlin, and Salt Creek townships where the thickness ranges in general from 3 feet 6 inches to about 6 feet. In physical character the limestone is a hard gray to bluish or brownish gray stone which is very fossiliferous. It generally occurs as a single heavy-bedded stratum which on prolonged weathering tends to split up into nodular layers 2 to 8 inches in thickness giving to the exposure a somewhat shaly appearance. Impurities in the form of iron oxide and chert are not conspicuous elements of the member. The Putnam Hill has been the chief source for limestone worked in Holmes County for local needs. Quarries have operated at various times in Knox, Hardy, Berlin, Salt Creek, Richland, and Paint townships. The chief products have been pulverized and calcined limestone for agricultural use and crushed stone for road purposes.

The Nashville Lime and Stone Quarries Company operates a quarry in the Putnam Hill limestone on the Harvey H. Martin property in Knox Township. The quarry is located about 1 1/2 miles southeast of Nashville and about one-half mile due south of Stone School. The limestone here has a thickness in excess of 5 feet.

Pulverized limestone for agricultural needs is the chief product of the quarry. A description of the rock exposures in the pit is as follows:

	Ft.	In.
Shale, weathered, and glacial drift	10	0
Limestone, dark blue, dense, hard; varies in thickness from 5 feet 2 inches to 5 feet 11 inches; Putnam Hill	5	6
Shale, black, carbonaceous	1	0
Coal, bony, Brookville or No. 4	1	0
Bottom of quarry.		

The Putnam Hill limestone exposed in this quarry was sampled by R. E. Lamborn for chemical analysis on May 8, 1941.

Sample No. 330

Chemical analysis of Putnam Hill limestone from quarry of the Nashville Lime and Stone Quarries Company near Nashville, Knox Township, Holmes County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	2.59
Alumina, Al_2O_3	0.83
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	0.83
Iron disulphide, FeS_2	0.09
Magnesium oxide, MgO	0.95
Calcium oxide, CaO	51.81
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.04
Water, hydroscopic, H_2O-	0.12
Water, combined, H_2O+	0.23
Carbon dioxide, CO_2	42.08
Titanium dioxide, TiO_2	0.05
Phosphorus pentoxide, P_2O_5	0.14
Sulphur trioxide, SO_3	0.03
Manganous oxide, MnO	0.09
Carbon, organic, C	0.10
Hydrogen, organic, H	0.01
Total	100.04

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis and is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.58
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.52
Silica, SiO_2	1.61
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	1.34
Iron disulphide, FeS_2	0.09
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO.P_2O_5$	0.30
Calcium sulphate, $CaO.SO_3$	0.05
Calcium carbonate, $CaO.CO_2$	92.14

Magnesium carbonate, $MgO.CO_2$	1.99
Manganese carbonate, $MnO.CO_2$	0.14
Water, hydroscopic, H_2O-	0.12
Organic matter	0.11
Unbalanced components (excess CO_2, H_2O)	-0.04
Total	100.04

The Putnam Hill limestone is quarried on a small scale by Andrew Swartzentruber in the east central part of Section 6, Salt Creek Township. Here the limestone has a thickness of about 5 feet 6 inches and is of good purity. Utilizing the underlying Brookville coal for fuel, the stone is calcined near the quarry and sold for agricultural use to the farmers in the community. The various rock strata exposed at the quarry are described below:

	Ft.	In.
Shale, weathered, and glacial drift	8	0
Limestone, bluish gray, weathers into nodular layers 2 to 8 inches in thickness, Putnam Hill	5	6
Clay shale	-	5
Coal (Brookville or No. 4)	-	11
Clay shale, gray (Brookville or No. 4)	-	2
Coal (Brookville or No. 4)	1	6
Bottom of exposure.		

A sample of the Putnam Hill limestone was secured from this quarry by R. E. Lamborn on May 23, 1941, for chemical analysis.

Sample No. 339

Chemical analysis of Putnam Hill limestone from quarry of Andrew Swartzentruber, Section 6, Salt Creek Township, Holmes County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	2.44
Alumina, Al_2O_3	0.88
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.70
Iron disulphide, FeS_2	0.11
Magnesium oxide, MgO	1.02
Calcium oxide, CaO	51.80
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.03
Potassium oxide, K_2O	0.10
Water, hydroscopic, H_2O-	0.22
Water, combined, H_2O+	0.25
Carbon dioxide, CO_2	41.98
Titanium dioxide, TiO_2	0.06
Phosphorus pentoxide, P_2O_5	0.21
Sulphur trioxide, SO_3	0.05
Manganous oxide, MnO	0.07
Carbon, organic, C	0.09
Hydrogen, organic, H	--
Total	100.03

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis with results as follows:

Silicates $\begin{cases}(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O \\ Al_2O_3.2SiO_2 2K_2O\end{cases}$	1.09 1.16
Silica, SiO_2	1.40
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.13
Iron disulphide, FeS_2	0.11
Titanium dioxide, TiO_2	0.06
Calcium phosphate, $3CaO.P_2O_5$	0.46
Calcium sulphate, $CaO.SO_3$	0.09
Calcium carbonate, $CaO.CO_2$	91.95
Magnesium carbonate, $MgO.CO_2$	2.13
Manganese carbonate, $MnO.CO_2$	0.11
Water, hydroscopic, H_2O-	0.22
Organic matter	0.09
Unbalanced components (deficiency CO_2, H_2O)	+0.01
Total	100.03

Pulverized limestone for agricultural use was being produced in 1941 at a quarry in the Putnam Hill member operated by E. E. Mullett and located on the A. E. Mullett property in the southwest quarter of Section 3, Salt Creek Township. As the limestone lies near the crest of a hill and occurs in good thickness for this member, a relatively large amount of stone can be produced with a minimum of stripping. When this place was visited in 1941, a kiln was being constructed for calcining the limestone. The beds exposed in the quarry are described below:

	Ft.	In.
Drift and weathered shale	8	0
Limestone, bluish gray, somewhat shattered on quarry face, Putnam Hill	6	0
Coal, weathered, Brookville or No. 4	1	0
Clay, gray, plastic	3	0

The 6-foot bed of Putnam Hill limestone worked in this quarry was sampled by R. E. Lamborn for chemical analysis on May 22, 1941.

Sample No. 336

Chemical analysis of Putnam Hill limestone from quarry operated by E. E. Mullett, Section 3, Salt Creek Township, Holmes County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	2.17
Alumina, Al_2O_3	0.68
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.74
Iron disulphide, FeS_2	0.02
Magnesium oxide, MgO	0.98
Calcium oxide, CaO	52.21
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	0.02
Water, hydroscopic, H_2O-	0.20
Water, combined, H_2O+	0.22
Carbon dioxide, CO_2	42.47
Titanium dioxide, TiO_2	0.04
Phosphorus pentoxide, P_2O_5	0.10
Sulphur trioxide, SO_3	0.04

Manganous oxide, MnO	0.18
Carbon, organic, C	0.02
Hydrogen, organic, H	--
Total	100.11

The per cent of each of the various compounds present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.17
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.56
Silica, SiO_2	1.37
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.19
Iron disulphide, FeS_2	0.02
Titanium dioxide, TiO_2	0.04
Calcium phosphate, $3CaO.P_2O_5$	0.22
Calcium sulphate, $CaO.SO_3$	0.07
Calcium carbonate, $CaO.CO_2$	92.92
Magnesium carbonate, $MgO.CO_2$	2.05
Manganese carbonate, $MnO.CO_2$	0.29
Water, hydroscopic, H_2O-	0.20
Organic matter, C	0.02
Unbalanced components (excess CO_2, H_2O)	-0.03
Total	100.11

Kaser Brothers' quarry in the Putnam Hill limestone is located on the north side of the valley of Upper Sand Run in the northeast quarter of Section 17, Hardy Township, one-half mile southeast of Armour School. The limestone is quarried by hand labor and the pulverized stone is sold for agricultural use, for which purpose it is well suited. The exposures on the outcrop are described as follows:

	Ft.	In.
Shale, weathered	5	0
Limestone, bluish gray, dense, one bed, weathering into irregular layers 2 inches to 1 foot in thickness, Putnam Hill	5	0
Covered interval	67	0
Limestone horizon, Lower Mercer	--	--

On May 21, 1941, a sample of limestone was cut from outcrops in this quarry by R. E. Lamborn for chemical analysis.

Sample No. 337

Chemical analysis of Putnam Hill limestone from quarry of Kaser Brothers, Section 17, Hardy Township, Holmes County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	1.82
Alumina, Al_2O_3	0.88
Ferric oxide, Fe_2O_3	0.08
Ferrous oxide, FeO	0.74
Iron disulphide, FeS_2	0.14
Magnesium oxide, MgO	0.95
Calcium oxide, CaO	52.21
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02

Potassium oxide, K_2O	0.09
Water, hydroscopic, H_2O-	0.15
Water, combined, H_2O+	0.23
Carbon dioxide, CO_2	42.35
Titanium dioxide, TiO_2	0.06
Phosphorus pentoxide, P_2O_5	0.16
Sulphur trioxide, SO_3	0.06
Manganous oxide, MnO	0.14
Carbon, organic, C	0.05
Hydrogen, organic, H	--
Total	100.13

The per cent of each of the various compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2 2H_2O$	1.01
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.24
Silica, SiO_2	0.78
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.09
Ferrous carbonate, $FeO.CO_2$	1.19
Iron disulphide, FeS_2	0.14
Titanium dioxide, TiO_2	0.06
Calcium phosphate, $3CaO.P_2O_5$	0.35
Calcium sulphate, $CaO.SO_3$	0.10
Calcium carbonate, $CaO.CO_2$	92.77
Magnesium carbonate, $MgO.CO_2$	1.99
Manganese carbonate, $MnO.CO_2$	0.23
Water, hydroscopic, H_2O-	0.15
Organic matter, C	0.05
Unbalanced components (excess CO_2, H_2O)	-0.02
Total	100.13

The Putnam Hill limestone was formerly stripped and quarried on the Irwin Horner property in the west central part of Section 18, Hardy Township. The quarry is located near the crest of the high ridge which overlooks the Killbuck Creek Valley to the eastward. The product of this quarry has been utilized for both agricultural lime and for road stone. The rock exposures are described as follows:

	Ft.	In.
Shale, gray, arenaceous	3	0
Limestone, gray to light bluish gray, weathering into nodular layers, 1 to 6 inches in thickness, Putnam Hill	3	2
Bottom of exposure.		

The 3 feet 2 inches of Putnam Hill exposed here was sampled on July 15, 1943, by R. E. Lamborn for chemical analysis.

Sample No. 411

Chemical analysis of Putnam Hill limestone from quarry on Irwin Horner property, Section 18, Hardy Township, Holmes County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	3.03
Alumina, Al_2O_3	0.90
Ferric oxide, Fe_2O_3	0.27

Ferrous oxide, FeO	0.56
Iron disulphide, FeS_2	0.24
Magnesium oxide, MgO	0.91
Calcium oxide, CaO	51.65
Sodium oxide, Na_2O	0.06
Potassium oxide, K_2O	0.15
Water, hydroscopic, H_2O-	0.06
Water, combined, H_2O+	0.42
Carbon dioxide, CO_2	41.41
Titanium dioxide, TiO_2	0.05
Phosphorus pentoxide, P_2O_5	0.06
Sulphur trioxide, SO_3	0.13
Manganous oxide, MnO	0.10
Total	100.00

The per cent of each of the mineral components in Sample No. 411 as determined by calculation (Lamborn) from the analysis is given below:

Silicates $(Na, K)_2 . 3Al_2O_3 . 6SiO_2 . 2H_2O$	2.01
Silicates $Al_2O_3 . 2SiO_2 . 2H_2O$	0.30
Silica, SiO_2	1.97
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.31
Ferrous carbonate, $FeO. CO_2$	0.90
Iron disulphide, FeS_2	0.24
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO, P_2O_5$	0.13
Calcium sulphate, $CaO. SO_3$	0.22
Calcium carbonate, $CaO. CO_2$	91.90
Magnesium carbonate, $MgO. CO_2$	1.90
Manganese carbonate, $MnO. CO_2$	0.16
Water, hydroscopic, H_2O-	0.06
Unbalanced components (excess CO_2, H_2O)	-0.15
Total	100.00

Vanport Member

The Vanport does not occur as a persistent or well developed member in the rock series exposed in Holmes County. It is represented by only occasional deposits of greenish ferruginous limestone measuring a few inches in thickness. Its economic possibilities in this county are trivial.

Hamden Member

The Hamden member is represented by occasional thin beds of dark fossiliferous shale or thin nodular iron ore. Limestone on the Hamden horizon is generally wanting in Holmes County.

Lower Freeport Limestone

Although its horizon outcrops over a few small areas in the eastern and southeastern parts, the Lower Freeport limestone has not been definitely recognized in this county.

JACKSON COUNTY [1]

General Considerations

The bedrocks which reach the surface in Jackson County have a total vertical thickness of about 920 feet. The lower 300 feet of this series consists of sandstones and shales belonging to the Cuyahoga and Logan formations of Mississippian age. Their outcrops occur over about 50 square miles located along the deeper valleys in Hamilton, Scioto, Liberty, Jackson, and Washington townships. The Mississippian is overlain by strata of Pennsylvanian age, which outcrop over an area of about 370 square miles or about seven-eighths of the area of the county. The Pennsylvanian beds likewise consist chiefly of sandstone and shale with only minor parts of coal, clay, limestone, and iron ore. The rock succession as described by Wilber Stout [2] with minor modifications [3] follows:

Generalized Section of Bedrocks Exposed in Jackson County

	Ft.	In.
Pennsylvanian system		
Conemaugh series		
Shales	30	0
Coal, Mason	1	0
Shale and sandstone	31	0
Coal, Mahoning	1	0
Sandstone, Mahoning	20	0
Allegheny series		
Coal, Upper Freeport or No. 7	3	0
Shales and sandstones	42	0
Coal, Lower Freeport or No. 6a	1	0
Shales and sandstones	37	0
Coal, Middle Kittanning or No. 6	1	10
Shales and sandstones	27	0
Ore, Red Kidney	--	4
Shales and sandstones	3	8
Clay, Oak Hill	3	0
Ore, Hamden	--	--
Shale	2	0
Coal	1	0
Shale	2	0
Coal } Lower Kittanning or No. 5	2	4
Clay } Lower Kittanning or No. 5	-	3
Coal } Lower Kittanning or No. 5	-	6
Clay	6	0
Shale and sandstone	6	6
Coal	-	6
Clay, shale, and sandstone	12	0
Ore, Ferriferous	-	6
Limestone, Vanport	6	0
Shale	1	0
Coal } Clarion or No. 4a	1	3
Clay } Clarion or No. 4a	-	7
Coal } Clarion or No. 4a	1	4

[1] *For a detailed description of the geology of Jackson County see Geology of Southern Ohio by Wilber Stout, Geol. Survey Ohio Bull. 20, pp. 15-274, 1916, from which much data on the geology of this county has been secured.*

[2] *Stout, Wilber, op. cit., pp. 26-28.*

[3] *Stout, Wilber, Geology of Vinton County: Geol. Survey Ohio Bull. 31, p. 70, 1927.*

Clay with pyrite	Clarion or No. 4a (cont.)	-	1
Coal	Clarion or No. 4a (cont.)	1	0
Clay		2	0
Sandstone		16	0
Coal, Winters		2	0
Ore	Zaleski	-	9
Flint	Zaleski	1	3
Shales and sandstone		27	6
Coal, Brookville or No. 4		2	0
Pottsville series			
Shales and sandstone		27	6
Ore and limestone, Upper Mercer		--	6
Shales and sandstone		14	8
Ore, Sand Block		-	4
Shale and sandstone		8	6
Coal, Upper Mercer or No. 3a		1	6
Shale and sandstone		18	0
Ore, Lower Mercer		-	4
Shale and sandstone		7	8
Limestone, Lower Mercer		1	0
Shale and sandstone		24	0
Ore, Boggs		-	6
Coal, Lower Mercer or No. 3		2	0
Shale and sandstone		25	0
Coal, Vandusen		1	0
Shale and sandstone		8	0
Ore, Jackson Sand Block		3	0
Shale and sandstone		12	0
Coal, Bear Run		2	0
Shale and sandstone		5	0
Ore, Kidney		-	6
Shale and sandstone		19	6
Coal, Quakertown or No. 2		3	0
Shale and sandstone		36	0
Ore, Guinea Fowl		-	6
Shale		3	0
Coal, Anthony		-	6
Clay, Sciotoville		5	0
Shale and sandstone		32	0
Ore, Sharon		-	6
Shale		5	6
Coal, Sharon or No. 1		3	0
Conglomerate, Sharon		60	0
Ore, Harrison		-	10

Mississippian system

	Ft.
Maxville formation	
Limestone, gray, very local	0 to 9
Logan formation	
Sandstones and sandy shales, yellowish brown, fine-grained, Vinton member	300 ±
Sandstones and fine-grained conglomerates, Allensville member	300 ±
Sandstone, shaly, and sandy shale, Byer member	300 ±

Cuyahoga formation
Shales, bluish gray, arenaceous and shaly sandstone, part exposed ....

Below the Cuyahoga formation sandstones and shales extend to a depth of several hundred feet. In deep wells drilled for oil and gas in Jackson County the Big Lime, which outcrops over large areas in the western half of Ohio, is encountered by the drill at depths below sea level varying from approximately 350 feet in the northwest part of Jackson Township to about 1,500 feet in the southeast corner of Madison Township.

Maxville Limestone

The Maxville limestone is present on the outcrop at only one locality in Jackson County, namely in Section 24, Hamilton Township. Here it is a gray limestone 9 feet in thickness which was formerly quarried for flux stone and road stone.

No large bodies of Maxville limestone are known to occur below drainage in Jackson County as the presence of this formation is not noted in the records of deep wells drilled to the Berea and Clinton sands for oil and gas.

Boggs Member

The Boggs member has been recognized at only a few places in Jackson County where it is represented by an iron carbonate ore measuring a few inches in thickness.

Lower Mercer Limestone

The distribution of the Lower Mercer limestone on the outcrop is confined chiefly to Lick, Coal, Milton, and Washington townships. In this area "its maximum development shows two benches of limestone each approximately one foot in thickness and separated by about 2 feet of shale." [1] It has been little utilized in this county.

Upper Mercer Limestone

The Upper Mercer limestone is present at only a few places on the outcrop in Jackson County and here it is represented by impure cherty limestone measuring a few inches in thickness. Where wanting its horizon is closely marked by the Upper Mercer ore.

Vanport Limestone

The field of outcrops of the Vanport limestone horizon extends entirely across Jackson County including western Madison and southeastern Jefferson townships, western Bloomfield and eastern Franklin townships, and eastern Lick, southeastern Coal, and much of Milton townships. In general the limestone is regular and persistent. It tends, however, to be thin and nodular in eastern Lick and southeastern Coal townships and it is often replaced by massive sandstone along the valleys of Raccoon Creek and Mulga Run from Keystone, Bloomfield Township, to Lincoln

[1] *Stout, Wilber, Geology of Southern Ohio: Geol. Survey Ohio Bull. 20, p. 142, 1916.*

Furnace, Milton Township. The thickness of the limestone, according to Stout, varies from 2 to 10 feet but averages about 6 feet. [1] Limestone on this horizon having a thickness of 5 to 7 feet is widespread in its occurrence. Flint nodules are often present but are confined for the most part to the upper part of member. In normal succession the Vanport is closely overlain by the well known Ferriferous ore and underlain by the Clarion coal. Open quarries and underground workings have operated in the Vanport at many places along the outcrop, yielding stone at various times for furnace flux, Portland cement, road mettle, and agricultural lime.

The Vanport limestone was formerly quarried for road stone in the southeast quarter of Section 29, Madison Township. In 1942 preparations were being made by Jenkins Brothers of Oak Hill to quarry the limestone around the margins of the old working for agricultural lime. The beds exposed here are described as follows:

		Ft.	In.
Shale, arenaceous		15	0
Limestone, bluish gray to light brownish gray, one layer, Vanport		5	0
Covered interval		2	9
Coal	Clarion or No. 4a	1	6
Parting	Clarion or No. 4a	-	2
Coal	Clarion or No. 4a	-	8
Bottom of exposure.			

The Vanport limestone having a thickness of 5 feet was sampled for chemical analysis on September 16, 1942, by R. E. Lamborn.

Sample No. 392

Chemical analysis of Vanport limestone from quarry of Jenkins Brothers, Section 29, Madison Township, Jackson County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	0.93
Alumina, Al_2O_3	0.11
Ferric oxide, Fe_2O_3	0.14
Ferrous oxide, FeO	0.99
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.63
Calcium oxide, CaO	53.64
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.06
Potassium oxide, K_2O	0.17
Water, hydroscopic, H_2O-	0.07
Water, combined, H_2O+	0.02
Carbon dioxide, CO_2	42.46
Titanium dioxide, TiO_2	<0.01
Phosphorus pentoxide, P_2O_5	0.14
Sulphur trioxide, SO_3	0.83
Manganous oxide, MnO	<0.01
Carbon, organic, C	0.09
Hydrogen, organic, H	<0.01
Total	100.28

[1] *Op. cit., p. 224.*

The per cent of each of the mineral constituents probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silica and hydrated aluminum silicates of sodium and potassium	1.27
Hydrated ferric oxide, $2FeO_3 . 3H_2O$	0.16
Ferrous carbonate, $FeO. CO_2$	1.59
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	<0.01
Calcium phosphate, $3CaO. P_2O_5$	0.31
Calcium sulphate, $CaO. SO_3$	1.41
Calcium carbonate, $CaO. CO_2$	94.41
Magnesium carbonate, $MgO. CO_2$	1.32
Water, hydroscopic, H_2O-	0.07
Organic matter	0.09
Unbalanced components, (excess CO_2)	-0.35
Total	100.28

A quarry in the Vanport limestone owned and operated by Iram Walton and Sons is located just southwest of the diagonal road in the east central part of Section 17, Bloomfield Township. A section of the rocks exposed in the quarry follows:

		Ft.	In.
Shale, bluish gray		19	6
Limestone, bluish gray, dense	Vanport	-	7
Limestone, bluish gray, somewhat laminated	Vanport	-	6
Limestone and black flint	Vanport	-	7
Limestone, gray to light bluish or brownish gray, dense to finely crystalline	Vanport	2	9
Limestone, gray to brownish gray, with occasional nodules of chert	Vanport	1	0
Limestone, bluish gray, dense to finely crystalline	Vanport	1	8
Coal, soft, shaly	Clarion or No. 4a	1	9
Shale parting	Clarion or No. 4a	-	9
Coal	Clarion or No. 4a	1	6
Parting	Clarion or No. 4a	-	1
Coal	Clarion or No. 4a	-	11
Bottom of exposure.			

Rejecting the 7-inch layer of limestone and black flint near the top of the member, the Vanport as described above was sampled by R. E. Lamborn on Sept. 16, 1942, for chemical analysis.

Sample No. 391

Chemical analysis of Vanport limestone from quarry of Iram Walton and Sons, Section 17, Bloomfield Township, Jackson County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	1.14
Alumina, Al_2O_3	0.37
Ferric oxide, Fe_2O_3	1.29
Ferrous oxide, FeO	0.63
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.77
Calcium oxide, CaO	51.56
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.09
Potassium oxide, K_2O	0.24
Water, hydroscopic, H_2O-	0.09
Water, combined, H_2O+	<0.01
Carbon dioxide, CO_2	42.38
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.11
Sulphur trioxide, SO_3	1.25
Manganous oxide, MnO	<0.01
Carbon, organic, C	0.42
Hydrogen, organic, H	0.05
Total	100.40

The per cent of each of the mineral constituents probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silica and hydrated aluminum silicates of sodium and potassium	1.84
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	1.51
Ferrous carbonate, $FeO. CO_2$	1.01
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.01
Calcium phosphate, $3CaO. P_2O_5$	0.24
Calcium sulphate, $CaO. SO_3$	2.13
Calcium carbonate, $CaO. CO_2$	90.23
Magnesium carbonate, $MgO. CO_2$	1.61
Water, hydroscopic, H_2O-	0.09
Organic matter	0.47
Unbalanced components (less CO_2, H_2O)	+1.26
Total	100.40

Hamden Member

The Hamden member is generally wanting in Jackson County except over small areas in Milton Township where it is represented by iron ore.

Upper and Lower Freeport Limestones

The horizons of the Lower and Upper Freeport limestones, which occur close below the Lower and Upper Freeport coal respectively, are due to outcrop in western Milton, eastern Bloomfield, and eastern Madison townships. Neither of these limestones has been definitely identified in Jackson County.

JEFFERSON COUNTY

General Considerations

Jefferson County represents an area of about 410 square miles located in that part of the maturely dissected, unglaciated section of the Allegheny Plateau drained by the Ohio River, which forms the eastern boundary of the county. The land surface is rough and rugged and bedrock outcrops are numerous. The relief varies from an average of about 520 feet in the eastern part to an average of about 250 feet at the western edge. The bedrocks outcropping in Jefferson County include the upper part of the Allegheny, the Conemaugh, and the Monongahela series of the Pennsylvanian system and the lower 126 feet of the Washington series of the Permian system. Owing to the regional attitude of the strata, which dip about 17 feet per mile in a direction 33° south of east, the outcrops of the oldest series exposed, the Allegheny, are limited to the valleys of Yellow Creek and the Ohio River in the northeastern part whereas younger and overlying series form the hills to the southward. The highest members stratigraphically are confined in their distribution to the ridge summits in Mount Pleasant Township. The total average thickness of the beds exposed is about 1, 050 feet. The various members and the details of the rock succession are given in the following generalized section. [1]

Generalized Section of Bedrocks Exposed in Jefferson County

	Ft.	In.
Permian system		
Washington series		
Limestone, with calcareous shale, Lower Washington	13	0
Shale	22	0
Coal, shaly Washington	3	0
Clay, dark	1	8
Shale and covered	51	0
Coal, Waynesburg A	4	8
Limestone, dark, massive, Mount Morris	--	10
Clay, dark	--	10
Shale, gray	8	9
Sandstone, Waynesburg	15	0
Limestone, Elm Grove	--	8
Shale, gray to dark	5	2
Pennsylvanian system		
Monongahela series		
Coal, Waynesburg	2	8
Clay, gray, arenaceous	5	4
Shale, arenaceous	13	4
Sandstone, locally developed, Gilboy	10	0
Shale, gray, arenaceous	14	9
Coal, shaly, unsteady, Uniontown	--	5
Clay and clay shale	4	4
Shale, gray	32	9
Limestone, marly, Arnoldsburg	12	10
Limestone, locally developed, Uniontown	1	4
Shale, gray	32	9
Shale, olive green, persistent, Fulton	5	8
Limestone, dark, persistent, with interbedded shale, Benwood	18	10
Shale, gray	19	4

[1] *Lamborn, R. E., Geology of Jefferson County: Geol. Survey Ohio Bull. 35, 1930.*

Shale, black, with shaly coal, Meigs Creek (Sewickley) or No. 9	1	1
Sandstone and shale	18	2
Shale, black, with shaly coal, Fishpot coal horizon	1	1
Shale, gray, arenaceous	11	0
Limestone with some interbedded shale, Fishpot	3	2
Shale, arenaceous	15	0
Sandstone, local, Pomeroy	--	8
Coal, persistent, Redstone or No. 8a	1	7
Clay, calcareous	3	6
Limestone, interbedded with shale, Redstone	9	1
Sandstone, locally developed, Upper Pittsburgh	11	1
Coal, shaly	1	2
Clay and clay shale	1	0
Coal (Pittsburgh or No. 8)	2	4
Parting (Pittsburgh or No. 8)	--	1/2
Coal (Pittsburgh or No. 8)	--	3
Parting (Pittsburgh or No. 8)	--	1/2
Coal (Pittsburgh or No. 8)	1	3
Parting (Pittsburgh or No. 8)	--	1/2
Coal (Pittsburgh or No. 8)	1	1
Conemaugh series		
Clay, gray	3	10
Limestone, local, Pittsburgh	2	7
Clay, gray	3	6
Shale, gray	9	3
Coal, local, Upper Little Pittsburgh	--	1
Clay, gray	5	6
Shale, gray	3	6
Sandstone, local, Bellaire	5	0
Shale, gray, arenaceous	12	2
Clay, with limestone, local, Summerfield	7	10
Shale, arenaceous	32	0
Sandstone, local, Connellsville	25	0
Coal, local, Clarksburg	1	0
Clay, with nodules and layers of limestone, Clarksburg	6	4
Shale, arenaceous	7	0
Sandstone, Morgantown	37	0
Coal, local, Elk Lick	--	7
Clay, with nodules of limestone, Elk Lick	6	2
Shale, gray, arenaceous	18	5
Limestone and shale, fossiliferous, Skelley	0	8
Coal, local, Duquesne	--	6
Clay, gray, plastic	6	2
Shale, gray	11	9
Limestone, fossiliferous, Ames	2	9
Shale, gray, arenaceous	17	0
Coal, Harlem	1	4
Clay, bluish	4	7
Shale, red and pink mottled, Round Knob	29	4
Coal, shaly, with black shale, Barton	--	2
Clay, with limestone nodules, Ewing	4	9
Shale, gray, arenaceous	22	0

Sandstone, local, Cow Run	18	0
Shale, arenaceous	18	0
Coal blossom, local Anderson	--	1
Clay, mottled	7	3
Shale, arenaceous	15	5
Limestone, ferruginous, fossiliferous, Cambridge	0	9
Coal blossom, local, Wilgus	0	1
Clay, arenaceous, ferruginous	6	1
Shale, arenaceous	18	3
Sandstone, local, Buffalo	15	0
Shale, gray, arenaceous	20	0
Shale, dark, with nodules of black limestone, fossiliferous, Brush Creek	8	2
Coal, shaly, Brush Creek	0	6
Clay with limestone nodules	6	0
Shale, arenaceous	25	10
Shale, black, with shaly coal, Mason	0	4
Clay, gray to pink mottled	4	0
Shale, arenaceous	15	7
Sandstone, local, Upper Mahoning	14	8
Coal, local, Mahoning	2	11
Clay, light, plastic, Thornton	5	4
Shale, arenaceous	12	3
Sandstone, local, Lower Mahoning	28	10
Allegheny series		
Coal, Upper Freeport or No. 7	2	8
Clay, plastic, arenaceous	4	0
Limestone, local, Upper Freeport	1	0
Clay, flint and plastic, Bolivar	5	0
Shale, arenaceous	30	0
Sandstone, local, Upper Freeport	16	0
Shale, arenaceous	6	8
Coal, Lower Freeport or No. 6a	2	6
Clay, plastic, arenaceous	2	4
Limestone, local, Lower Freeport	1	0
Clay, plastic, arenaceous	3	0
Sandstone, massive, local, Lower Freeport	30	0
Shale, with ore nodules	11	0
Shale, black, fossiliferous, Washingtonville	1	4
Shale, dark, with ore nodules	6	2
Coal, Middle Kittanning or No. 6	2	2
Clay	4	11
Shale and sandstone	25	8
Coal, Lower Kittanning	2	10
Clay, plastic	5	4
Clay, arenaceous	4	1
Shale and shaly sandstone	20	0

Nineteen limestone-bearing horizons have been recognized in the long rock column exposed in Jefferson County. Many of these limestones are so thin and so restricted in their areal distribution that their importance is stratigraphic rather than economic in nature. The best developed limestones outcropping in this county are the Ames, Summerfield, Benwood, and Arnoldsburg members. Small quarries have operated for the production of agricultural lime and road stone in Salem, Smithfield, Warren, and Wayne townships. The distribution and thickness of the limestones are treated briefly in following paragraphs.

No limestones of mineable proportions are known to occur within a reasonable distance below the lowest outcrops in Jefferson County. The Maxville limestone is wanting in this area. The next lime-bearing series in descending order, the Devonian limestones, is first encountered in deep test wells drilled for oil and gas at depths below sea level in excess of 3,000 feet.

Lower Freeport Limestone

The known outcrops of the Lower Freeport limestone are confined to a few localities in Salem, Brush Creek, and Knox townships where it varies in thickness from a few inches to nearly 2 feet. For an analysis of the Lower Freeport limestone see pages of this report dealing with this member in Columbiana County.

Upper Freeport Limestone

The Upper Freeport limestone has no economic importance in Jefferson County for the member is always thin and its occurrence is confined to a very few scattered localities in Saline, Ross, Springfield, and Island Creek townships.

Brush Creek Member

The Brush Creek beds in this county consist almost entirely of dark fossiliferous shales with only occasional nodules or thin nodular layers of dark limestone. In Saline, Brush Creek, Ross, Springfield, Knox, and Island Creek townships where the Brush Creek beds outcrop the average thickness of these shales is about 8 feet.

Cambridge Limestone

The Cambridge limestone outcrops in every township in the northern two-thirds of this county. Measurements of the member at widely scattered localities show variations in thickness ranging from 1 inch to 2 feet 4 inches with a mean of about 9 inches. No economic importance can be attached to the Cambridge in Jefferson County.

Ewing Limestone

The known deposits of Ewing limestone in Jefferson County are confined to a few scattered localities in Knox and Island Creek townships where it is generally nodular in character and rarely exceeds 1 foot in thickness. Elsewhere on the outcrop sandstone and sandy shale occupy the Ewing horizon.

Ames Limestone

The horizon of the Ames limestone is present above drainage in every township in Jefferson County with the exception of Smithfield and Mount Pleasant in the southeastern part. The position of the limestone in vertical scale in this area is on an average about 212 feet below the Pittsburgh coal and about an equal distance above the Brush Creek shale. Owing to replacement by the Morgantown sandstone the Ames is generally wanting where due in Brush Creek Township, in northern Springfield Township, and in northern Ross Township. For the same reason its occurrence is spotted in Salem, Knox, Steubenville, and Cross Creek townships. The thickness of the Ames limestone on the outcrop in Jefferson County varies from a few inches to about 12 feet. The character of the stone tends to be typical for this member although in parts of Knox and Island Creek townships it is somewhat shaly and impure. It reaches its thickest development in Salem and Wayne townships where it has been quarried from time to time for road stone and for agricultural lime. In the days of the charcoal furnaces, the Ames limestone was quarried in northern Saline Township and utilized for flux stone at Irondale. [1]

Along the valley of Lea Branch in the east central part of Section 33, Salem Township, the Ames limestone has been quarried on the R. B. Barnes property for both road stone and agricultural lime. A description of the exposures in the quarry is as follows:

		Ft.	In.
Soil and mantle rock		1	0
Limestone, bluish gray, somewhat crystalline, heavy-bedded	Ames	4	0
Limestone, bluish gray, more dense in texture		2	8
Bottom of quarry.			

The part of the Ames limestone exposed at this locality having a thickness of 6 feet 8 inches was sampled by R. E. Lamborn on July 30, 1941, for chemical analysis.

Sample No. 361

Chemical analysis of Ames limestone from quarry on R. B. Barnes property, Section 33, Salem Township, Jefferson County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	5.11
Alumina, Al_2O_3	1.58
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	1.17
Iron disulphide, FeS_2	0.03
Magnesium oxide, MgO	0.90
Calcium oxide, CaO	49.30
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.06
Water, hydroscopic, H_2O-	0.45
Water, combined, H_2O+	0.40
Carbon dioxide, CO_2	40.36
Titanium dioxide, TiO_2	0.05
Phosphorus pentoxide, P_2O_5	0.16
Sulphur trioxide, SO_3	0.07
Manganous oxide, MnO	0.31
Carbon, organic, C	0.02
Hydrogen, organic, H	--
Total	100.02

[1] *Stout, Wilbur, and Lamborn, R. E., Geology of Columbiana County: Geol. Survey Ohio Bull. 28, p. 351, 1924.*

The per cent of each of the compounds probably present in Sample No. 361 has been computed (Lamborn) from the chemical analysis.

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.75
Hydrated silicates $Al_2O_3.2SiO_2.2H_2O$	3.26
Silica, SiO_2	3.25
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.03
Ferrous carbonate, $FeO.CO_2$	1.89
Iron disulphide, FeS_2	0.03
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO.P_2O_5$	0.35
Calcium sulphate, $CaO.SO_3$	0.12
Calcium carbonate, $CaO.CO_2$	87.57
Magnesium carbonate, $MgO.CO_2$	1.88
Manganese carbonate, $MnO.CO_2$	0.50
Water, hydroscopic, H_2O-	0.45
Organic matter	0.02
Unbalanced components (excess CO_2, H_2O)	-0.13
Total	100.02

The Ames limestone was formerly quarried for road stone on the Tipton property in Section 36, Wayne Township. The quarry is located along a small valley just north of the road in the central part of the section. The writer's description of the exposures is as follows:

		Ft.	In.
Soil and mantle rock		2	0
Limestone, bluish to brownish gray, one layer	Ames	--	10
Limestone, bluish to brownish gray, in nodular layers 2 to 7 inches thick separated by paper shale partings	Ames	1	10
Limestone, bluish gray, somewhat nodular	Ames	2	6
Shale, bluish gray, calcareous	Ames	--	1
Limestone, bluish gray, one layer	Ames	--	7
Bottom of quarry.			

In all probability the bottom of the Ames limestone at this locality lies below the quarry floor and the full thickness of the member is not therefore represented in the description given above. The bedrocks exposed, with the exception of the 1-inch shale near the base of the outcrop, were sampled by R. E. Lamborn on July 31, 1942, for chemical analysis.

Sample No. 362

Chemical analysis of Ames limestone from Tipton quarry, Section 36, Wayne Township, Jefferson County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	9.35
Alumina, Al_2O_3	1.55

Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.81
Iron disulphide, FeS_2	0.02
Magnesium oxide, MgO	0.92
Calcium oxide, CaO	47.32
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.08
Water, hydroscopic, H_2O-	0.48
Water, combined, H_2O+	0.36
Carbon dioxide, CO_2	38.61
Titanium dioxide, TiO_2	0.05
Phosphorus pentoxide, P_2O_5	0.15
Sulphur trioxide, SO_3	0.06
Manganous oxide, MnO	0.25
Carbon, organic, C	0.02
Hydrogen, organic, H	--
Total	100.07

The per cent of each of the compounds probably present in the sample computed (Lamborn) from the chemical analysis is as follows:

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.92
Hydrated silicates $Al_2O_3.2SiO_2.2H_2O$	3.02
Silica, SiO_2	7.52
Hydrated ferric oxide, $2FeO_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.31
Iron disulphide, FeS_2	0.02
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO.P_2O_5$	0.33
Calcium sulphate, $CaO.SO_3$	0.10
Calcium carbonate, $CaO.CO_2$	84.07
Magnesium carbonate, $MgO.CO_2$	1.92
Manganese carbonate, $MnO.CO_2$	0.40
Water, hydroscopic, H_2O-	0.48
Organic matter	0.02
Unbalanced components (excess CO_2, H_2O)	-0.11
Total	100.07

Skelley Limestone

The distribution of the Skelley limestone, first named by Condit for exposures near Skelley, [1] is confined for the most part to Wayne, Steubenville, and Cross Creek townships. Here the limestone varies in thickness from 3 inches to 1 foot 6 inches and tends to be more impure than the Ames limestone found from 11 to 26 feet below it.

Elk Lick Limestone

Known exposures of the Elk Lick member are confined to small areas in Island Creek and Salem townships, where it consists of thin limestone, 1 foot or so in thickness, embedded in the Elk Lick clay.

[1] *Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17, p. 208, 1912.*

Clarksburg Limestone

Like the Elk Lick in physical aspect and mode of occurrence is the Clarksburg limestone which is found some 50 feet higher in the section. It is very patchy in distribution but has been noted at a few localities in Island Creek, Cross Creek, Steubenville, Smithfield, and Warren townships where its usual thickness varies from a few inches to 1 or 2 feet. Its economic possibilities are negligible.

Summerfield Limestone

The Summerfield limestone has been recognized at a few localities in Salem, Cross Creek, Steubenville, Smithfield, Mount Pleasant, and Warren townships where it is either nodular in character or is made up of one or more thin layers embedded in clay having an aggregate thickness of less than 3 feet. Its usual position is about 45 feet below the Pittsburgh coal.

Pittsburgh Limestone

The Pittsburgh limestone is often present, either in nodular or bedded form, along the outcrop of its horizon in Springfield, Knox, Salem, Cross Creek, Smithfield, Mt. Pleasant, and Warren townships but it is generally more persistent and regular in Mount Pleasant Township. The thickness of the limestone varies from a few inches to about 8 feet. It is generally separated from the Pittsburgh coal by a few feet of calcareous clay. For an analysis of the Pittsburgh limestone see Sample No. 369, secured in Flushing Township, Belmont County.

Redstone Limestone

The Redstone limestone is widely distributed in Jefferson County where it is found on an average about 3 feet 6 inches below the Redstone coal and about 11 feet above the top of the Pittsburgh coal. In Springfield, Salem, and Island Creek townships the limestone is generally thin and patchy and its areas of occurrence are generally small in extent. In Cross Creek, Wayne, Wells, and Smithfield townships this limestone is likewise patchy in distribution but in places it measures 10 feet or more in thickness. It is a constant element of the section in Mt. Pleasant and Warren townships. The thickness of the limestone and interstratified shales in Jefferson County varies from 1 to 18 feet with an average of about 9 feet. Inspection of the stone suggests that it has a relatively high content of silica and argillaceous material and that it is not especially rich in calcium carbonate.

Fishpot Limestone

Outcrops of the Fishpot limestone have been noted at widely scattered localities in Cross Creek, Smithfield, Wells, and Warren townships where it is found on an average about 40 feet above the Pittsburgh coal. It is a fairly continuous element of the series in Warren Township south of Short Creek. The thickness of the limestone in this county varies from a few inches to about 13 feet with an average of about 3 feet. Analyses of the Fishpot limestone are given in part of this report dealing with the member in Belmont County.

Benwood Limestone

The Benwood limestone occurring in the interval between the Meigs Creek coal and the Fulton Green shale is generally present on the outcrop in Cross Creek, Smithfield, Mt. Pleasant, Wells, and Warren townships. Consisting of limestone layers interstratified with calcareous shale, the member varies in thickness in this county from about 5 to 45 feet. The limestone was formerly quarried in a small way in the northeastern part of Section 23 and in the southeastern quarter of Section 33, Smithfield Township. In Warren Township this limestone has been pulverized for agricultural use to a limited extent about 1 mile north of Connorville in Section 19. An analysis of the Benwood limestone is given in pages of this report dealing with the member in Belmont County.

Arnoldsburg Limestone

The Arnoldsburg member includes gray to buff, marly, limestone interstratified with calcareous shale lying close above the Fulton Green shale. Limestone representing the Arnoldsburg has been recognized on the outcrop in parts of Wayne, Cross Creek, Smithfield, Mt. Pleasant, and Warren townships where it is generally thin and argillaceous in character.

Uniontown Limestone

In Smithfield and Warren townships where the Uniontown limestone has been recognized it is a thin bed ranging from 6 inches to 2 feet 6 inches in thickness and occurring on an average about 4 feet 6 inches below the Uniontown coal. Its economic importance is negligible in this county.

Elm Grove Limestone

The distribution of the Elm Grove limestone is limited to a very few localities near the crests of the highest ridges in Wells, Warren, and Mt. Pleasant townships. In these localities the limestone is generally 6 to 8 inches in thickness and its position is close above the Waynesburg coal.

Mount Morris Limestone

The Mount Morris limestone has been noted at only two localities in Mt. Pleasant Township, where it consists of 1 foot or less of limestone lying close below the Waynesburg A coal.

Lower Washington Limestone

The Lower Washington limestone has been recognized in Section 23, Mt. Pleasant Township. Here the limestone, which has been quarried for road stone, together with the interstratified shale, measures 13 feet 3 inches in thickness.

KNOX COUNTY

General Considerations

In Knox County the bedrock series forming the floor below the glacial drift and outcropping along the hillsides is made up of strata of Mississippian and Pennsylvanian ages. The Mississippian system is represented by sandstones and shales of the Logan and Cuyahoga formations. They are the first bedrocks encountered over about 95 per cent of the county and their outcrops represent a vertical thickness of approximately 700 feet. The Maxville limestone, which overlies the Logan formation over small areas in east central Ohio, is wanting in Knox County. Along the high ridges in Jefferson, Union, Butler, and Jackson townships in the eastern part, the Mississippian beds are capped by strata of Pottsville age approximately 200 feet in thickness. This latter series likewise consists in large part of sandstone and shale, but the Mercer limestones are expected close below the summits of high knobs and ridges in the southeastern part of the county.

Below the rock series exposed in Knox County, shales predominate to depths of several hundreds of feet. Below these shales the Middle Devonian limestones are next encountered. These limestones are reached in wells at levels ranging from 200 feet above sea level along the western edge to approximately 1,000 feet below sea level in the southeastern corner of the county.

LAKE COUNTY

General Considerations

The bedrocks which reach the surface over the 232 square miles included in Lake County contain no potential resources of limestone. The outcropping beds consist chiefly of shale and sandstone with a small amount of conglomerate. The Chagrin shale of upper Devonian age is the lowest outcropping formation along the lake shore. Younger subdivisions, including the Cleveland shale, Bedford shale, Berea sandstone, and Cuyahoga sandstones and shales, outcrop successively up the escarpment to the south. Little Mountain and a few other high hills along the southern boundary of the county are capped with Sharon conglomerate of Pottsville age. The total thickness of the sedimentary series reaching the surface in this county is close to 700 feet.

Underlying the Ohio shale, of which the Chagrin shale previously mentioned is the thickest subdivision, there is a thick rock series consisting chiefly of limestone and dolomite with some beds of salt, gypsum, and shale, which is generally known among well drillers as the Big Lime. The Big Lime occurs in Lake County at depths below sea level ranging about 550 feet near Wickliffe, Willoughby Township, to approximately 800 feet in northeastern Kirtland, southeastern Leroy, and southeastern Madison townships. Salt from the Big Lime is utilized at the plant of the Diamond Alkali Company at Fairport.

LAWRENCE COUNTY [1]

General Considerations

The bedrocks which reach the surface in Lawrence County belong to the Pottsville, Allegheny, Conemaugh, and Monongahela series of the Pennsylvanian system and consist in large part of sandstone and shale with minor amounts of coal, clay, limestone, and iron ore. The general altitude of the beds is that of a moderate slope amounting to 26.7 feet per mile in a direction 20° 48' south of east. [2] As a consequence of this dip, the strata of Pottsville and Allegheny ages, which form the outcrops in the western part of the county, pass below drainage when traced to

[1] *For detailed accounts of the geology of Lawrence County see the following: Stout, Wilber, Geology of southern Ohio: Geol. Survey Ohio Bull. 20, pp. 275-424, 1916; Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17, pp. 60-74, 1912; Bownocker, J. A. and Dean, Ethel S, Analyses of the coals of Ohio: Geol. Survey Ohio Bull. 34, 1930.*

[2] *Stout, Wilber, Geology of southern Ohio: Geol. Survey Ohio Bull. 20, p. 282, 1916.*

the east and in Rome, Mason, Union, and Windsor townships are deeply buried below the Conemaugh and Monongahela series. The total thickness of the Pennsylvanian beds cropping out in Lawrence County is approximately 1,000 feet. Below the Pennsylvanian, strata of Mississippian age are due close above the level of the Ohio River in the southwestern corner of Hamilton Township, but here possible bedrock exposures are masked by alluvial deposits. A generalized section of the Pennsylvanian series showing the average thickness of members and of sandstone and shale intervals has been compiled from published and unpublished data as follows:

Generalized Section of Pennsylvanian Strata
Outcropping in Lawrence County

Pennsylvanian system	Ft.	In.
Monongahela series		
Sandstone, shale, coal, clay, unclassified. Approximate thickness	260	0
Conemaugh series		
Clay, with a little nodular limestone	3	0
Shale, sandy, and thin-bedded sandstone	37	0
Sandstone, coarse-grained, Connellsville	30	0
Coal streak, Clarksburg	-	-
Shale	18	0
Sandstone, shaly to massive	20	0
Clay shale, red	20	0
Limestone, nodular, Elk Lick (?)	1	0
Shale, sandy	8	0
Sandstone, Morgantown	30	0
Shale, sandy	12	0
Clay shale, red, with nodules of limestone and hematite. Replaced by shaly sandstone in some localities	36	0
Limestone, impure, fossiliferous, Portersville	-	8
Coal, thin, Anderson	-	-
Clay shale	37	0
Limestone, not persistent, fossiliferous, Cambridge	2	0
Shale, carbonaceous	2	0
Coal, Wilgus	2	0
Clay shale	17	0
Limestone, impure, fossiliferous, cherty in some localities	2	0
Shale — Brush Creek	14	0
Limestone, impure, fossiliferous, frequently missing	1	6
Shale, sandy, and flaggy sandstone	23	0
Coal, thin, Mason	-	-
Clay, pale red	8	0
Sandstone, shaly	15	0
Coal, thin, Mahoning	-	-
Sandstone	24	0
Allegheny series		
Coal, locally present, Upper Freeport or No. 7	3	5

Clay	2	0
Sandstone and shale, Upper Freeport sandstone horizon	38	0
Coal, local, Lower Freeport or No. 6a	1	8
Clay	2	6
Sandstone and shale, Lower Freeport sandstone horizon	38	0
Coal, with partings, Middle Kittanning or No. 6	2	0
Clay	3	6
Sandstone and shale	25	0
Clay, very local, Oak Hill	2	0
Coal, local, "Lost Seam"	1	0
Shale	3	0
Coal, with partings, Lower Kittanning or No. 5	3	3
Clay, gray	4	0
Limestone, generally gray, fossiliferous, Vanport	6	1
Coal, with partings, Clarion or No. 4a	3	9
Clay	5	0
Sandstone, Clarion	24	0
Coal, very local, Winters	1	0
Shale and sandstone	26	0
Coal, with partings, Brookville or No. 4	3	0
Pottsville series		
Clay	4	0
Shale and sandstone	28	0
Ore, Upper Mercer	1	0
Limestone, wanting, Upper Mercer	-	-
Shale	12	0
Ore, siliceous, Sand Block	-	8
Shale and sandstone	12	8
Coal, with shale partings, Upper Mercer or No. 3a	3	1
Shale	25	0
Ore, Lower Mercer	-	5
Limestone, local, Lower Mercer	1	0
Shale and sandstone	37	6
Shale, with thin ore bands, Boggs	3	0
Shale	3	0
Coal, Lower Mercer or No. 3	1	6

The limestones of the Pennsylvanian system are in general not well developed on the outcrop in Lawrence County. Some members which are well expressed in the central part of the belt of outcrops in Ohio thin, become nodular in character, or disappear to the south, their position being closely marked by fossiliferous shale, by red clay shale, or by nodular iron ore. Other beds in their extension southward become highly siliceous and impure. In Lawrence County those members of the Pennsylvanian which are best developed and which have received the most attention as sources for limestone are the Vanport, Brush Creek, and Cambridge. Quarries have operated at various times in Elizabeth, Decatur, Washington, Mason, Symmes, Aid, Windsor, and Lawrence townships for the production of stone for furnace flux, Portland cement, agricultural lime, and for road construction.

Below drainage in Lawrence County the Maxville limestone has been encountered by the drill in many wells sunk for oil and gas. For years this limestone has been mined by shafting at Ironton and utilized for the manufacture of Portland cement. Below the Maxville, sandstones and shales extend downward for many hundreds of feet until the Big Lime is reached at depths below sea level ranging from 1,000 feet along the west edge of Hamilton, Elizabeth, Decatur, and Washington townships to approximately 2,500 feet in the eastern part of Rome Township in the southeastern part of the county.

Maxville Limestone

In the southeast part of Hamilton Township where the top of the Mississippian lies close above drainage, the sandstones and shales of the Pennsylvanian are found immediately overlying the Logan with the Maxville limestone wanting from the section. Below drainage, however, thick deposits of Maxville have been penetrated in drilling wells for oil and gas in the southern and eastern parts of the county. The largest area so far known includes much of Union Township, the southern half of Rome Township, and the southern edge of Windsor Township. In this field the limestone formation has a thickness, according to the records of scattered wells, which is uniformly in excess of 100 feet with many depths greater than 150 feet. Only one shale "break" is generally recorded in the formation. This is the "pencil cave" of the driller and is usually less than 10 feet in thickness. This field may be extended to the north in Rome and Windsor townships and to the west in Union and Fayette townships by further exploration with the drill.

The second known area of Maxville limestone occurring below drainage in Lawrence County is found to the east and southeast of Ironton. It includes in general the western part of Perry Township, Lawrence Township southwest Kitts Hill, and the western part of Upper Township south of Hecla in Section 14. Extensions of this area to the north, northeast, east, and southeast are possible through further explorations with the drill. The thickness of the limestone in this area is generally less than 100 feet with many records in eastern Upper Township showing the Maxville ranging from 75 to 90 feet thick. Test holes drilled near the shaft of the Alpha Portland Cement Company show the limestone to be 97 feet in thickness at that locality.

The third area supported by little drillers' evidence is believed to extend from Moulton, Decatur Township, in a direction west of north past Olive Furnace, Washington Township, into eastern Bloom Township, Scioto County, where the limestone was reached by the Harper shaft. A well drilled a number of years ago on the McGugin property near Olive Furnace penetrated 43 feet of the Maxville limestone at a depth of 157 feet. Wells drilled on the Henderson and Carlyle properties in sections 4 and 30, Aid Township, passed through limestone at the Maxville horizon varying from 55 to 65 feet in thickness.

The plant of the Alpha Portland Cement Company, formerly owned by the Ironton Portland Cement Company, is located about 2 miles above Ironton near the mouth of the valley of Ice Creek in the southeast quarter of Section 26, Upper Township. Limestone for the plant is supplied from a shaft mine in the Maxville 510 feet in depth. The bottom of the shaft is approximately 55 feet below the top limestone which in this locality has been determined by a core drill test to have a thickness of about 97 feet. When this mine was visited in 1943 a limestone face about 40 feet in height was being worked. Solid limestone forms the roof and the floor of the mine. The chief features of the limestone exposed on the working face of the mine are described as follows:

	Ft.	In.
Limestone, gray to light bluish gray, somewhat siliceous	13	6

Limestone, dark, dense, carbonaceous, somewhat shaly and impure	4	6
Limestone, gray to light brownish gray, generally dense texture	21	8
Floor of mine.		

A sample of the 39 feet 8 inches of Maxville limestone described above was secured by R. E. Lamborn on September 1, 1943, for chemical analysis.

Sample No. 416

Chemical analysis of Maxville limestone from shaft mine of the Alpha Portland Cement Company at Ironton, Upper Township, Lawrence County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	8.84
Alumina, Al_2O_3	1.47
Ferric oxide, Fe_2O_3	0.75
Ferrous oxide, FeO	0.62
Iron disulphide, FeS_2	0.21
Magnesium oxide, MgO	2.68
Calcium oxide, CaO	45.54
Sodium oxide, Na_2O	0.07
Potassium oxide, K_2O	0.55
Water, hydroscopic, H_2O-	0.15
Water, combined, H_2O+	0.59
Carbon dioxide, CO_2	38.26
Titanium dioxide, TiO_2	0.12
Phosphorus pentoxide, P_2O_5	0.02
Sulphur trioxide, SO_3	0.08
Manganous oxide, MnO	0.03
Total	99.98

As determined by calculation (Lamborn) from the chemical analysis the per cent of each of the mineral components in Sample No. 416 is as follows:

Silica and hydrated aluminum silicates of sodium and potassium	11.39
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.88
Ferrous carbonate, $FeO.CO_2$	1.00
Iron disulphide, FeS_2	0.21
Titanium dioxide, TiO_2	0.12
Calcium phosphate, $3CaO.P_2O_5$	0.04
Calcium sulphate, $CaO.SO_3$	0.14
Calcium carbonate, $CaO.CO_2$	81.14
Magnesium carbonate, $MgO.CO_2$	5.60
Manganese carbonate, $MnO.CO_2$	0.05
Water, hydroscopic, H_2O-	0.15
Unbalanced components (excess CO_2)	-0.74
Total	99.98

Boggs Member

The Boggs member in Lawrence County is represented by scattered deposits of kidney ore closely overlying the Lower Mercer coal along the valley of Pine Creek in western Elizabeth Township, to which its outcrops are chiefly confined.

Lower Mercer Limestone

The known outcrops of Lower Mercer limestone in this county are confined to a few localities in the vicinity of Kelleys Mills, Elizabeth Township, where it measures a foot or less in thickness.

Upper Mercer Limestone

The Upper Mercer limestone is wanting on the outcrop in this county. Across Washington, Decatur, Elizabeth, Hamilton, and Upper townships where the limestone is due, its position is closely marked by the Upper Mercer ore.

Vanport Limestone

The widespread distribution of the outcrops, good development, and excellent quality of the Vanport make it an important source of limestone in Lawrence County. Since early times this limestone has been worked extensively both by stripping along the outcrop and by underground methods and has been utilized from time to time for furnace flux, Portland cement, concrete aggregate, road ballast, agricultural lime, and for rough construction work. The belt of outcrops of the Vanport limestone extends entirely across Lawrence County from Perry, Upper, and Hamilton townships on the south to Washington Township on the north. The thickest and most continuous deposits on the outcrop are found in Washington and Decatur townships in Elizabeth Township east of Pine Creek and east of Pine Grove south of Pine Creek; and in Upper Township north of Ice Creek. In Upper Township south of Ice Creek and in western Perry Township north of Sheridan this limestone is generally thin and patchy in distribution. It is in most places wanting in eastern Hamilton, thin and flinty in western Hamilton, and irregular in both thickness and occurrence in western Elizabeth Township. In the best part of the field in Lawrence County the thickness of the Vanport varies from 6 to 9 feet with an average of about 7 feet. The limestone is generally bluish to brownish gray in color, dense in texture, and heavy bedded in structure. Flint nodules are of common occurrence in the upper foot or so of the member. The limestone is closely overlain by the Ferriferous ore and underlain by the Clarion coal and clay. Sandstone is generally present above the limestone and ore in north central Elizabeth Township and in southern Washington Township. In Lawrence County quarries in the Vanport member have operated at various times in Washington, Decatur, Elizabeth, and Upper townships.

The Vanport limestone is well exposed along the roadside in the south central part of Section 23, Washington Township, where the highway crosses Brodys Run. Here the full thickness of the limestone is exposed as described below.

		Ft.	In.
Shales and covered		-	-
Limestone, gray to light bluish gray	Vanport	1	6
Limestone, gray to light bluish gray, fossiliferous, one layer	Vanport	4	0
Shale		-	4

The limestone at this locality having a thickness of 5 feet 6 inches was sampled by R. E. Lamborn, Sept. 17, 1942, for chemical analysis.

Sample No. 394

Chemical analysis of Vanport limestone from outcrop in Section 23, Washington Township, Lawrence County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	0.67
Alumina, Al_2O_3	0.36
Ferric oxide, Fe_2O_3	0.56
Ferrous oxide, FeO	0.71
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.60
Calcium oxide, CaO	53.13
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.05
Potassium oxide, K_2O	0.20
Water, hydroscopic, H_2O-	0.05
Water, combined, H_2O+	<0.01
Carbon dioxide, CO_2	43.42
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.07
Sulphur trioxide, SO_3	0.32
Manganous oxide, MnO	<0.01
Carbon, organic, C	0.09
Hydrogen, organic, H	0.01
Total	100.25

The per cent of each of the mineral constituents probably present in the sample as calculated (Lamborn) from the chemical analysis is given below:

Silica and hydrated aluminum silicates of sodium and potassium	1.28
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.66
Ferrous carbonate, $FeO.CO_2$	1.15
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	<0.01
Calcium phosphate, $3CaO.P_2O_5$	0.15
Calcium sulphate, $CaO.SO_3$	0.54
Calcium carbonate, $CaO.CO_2$	94.28
Magnesium carbonate, $MgO.CO_2$	1.25
Water, hydroscopic, H_2O-	0.05
Organic matter	0.10
Unbalanced components (lacking CO_2)	+0.78
Total	100.25

The plant and mine of the Buckeye Coal and Lime Company is located just south of Nigger Creek about 1 mile east of its mouth in the northwest quarter of Section 11, Decatur Township. The Vanport limestone, which has a total thickness of about 6 feet 6 inches, is worked by drift mining. The upper part of the limestone which is somewhat flinty in character is left for a roof in the mine. The stone is pulverized at the plant and sold as agricultural lime. A section in the mine, including the underlying Clarion coal, the structure of which was reported in part by Mr. E. P. Collins, manager of the company, is given below.

		Ft.	In.
Ore, Ferriferous		1	0
Limestone, somewhat flinty	Vanport	2	0

			Ft.	In.
Limestone, gray, tough, compact, fossiliferous	Vanport (cont.)		3	1
Limestone, dark bluish gray, tough, compact, fossiliferous			1	5
Shale			-	2
Coal	Clarion or No. 4a		1	0
Clay shale parting			-	5 1/2
Coal			1	6
Clay shale, with pyrite			-	2
Coal			-	6
Shale parting			-	8
Coal			1	0
Clay			6	0

The lower 4 feet 6 inches of the Vanport limestone, the part mined at this locality, was sampled by R. E. Lamborn on September 17, 1942, for chemical analysis.

Sample No. 393

Chemical analysis of Vanport limestone from quarry of Buckeye Coal and Lime Company, Section 11, Decatur Township, Lawrence County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	0.78
Alumina, Al_2O_3	0.44
Ferric oxide, Fe_2O_3	1.31
Ferrous oxide, FeO	0.61
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.65
Calcium oxide, CaO	51.55
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.08
Potassium oxide, K_2O	0.22
Water, hydroscopic, H_2O-	0.10
Water, combined, H_2O+	0.04
Carbon dioxide, CO_2	42.43
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.10
Sulphur trioxide, SO_3	1.28
Manganous oxide, MnO	<0.01
Carbon, organic, C	0.50
Hydrogen, organic, H	0.04
Total	100.14

The per cent of each of the mineral compounds in the sample as determined by calculation (Lamborn) from the analysis is given below.

Silica and hydrated aluminum silicates of sodium and potassium	1.52
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	1.53
Ferrous carbonate, $FeO.CO_2$	0.98

Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.01
Calcium phosphate, $3CaO.P_2O_5$	0.22
Calcium sulphate, $CaO.SO_3$	2.17
Calcium carbonate, $CaO.CO_2$	90.20
Magnesium carbonate, $MgO.CO_2$	1.36
Water, hydroscopic, H_2O-	0.10
Organic matter	0.54
Unbalanced components (lacking CO_2, H_2O)	+1.51
Total	100.14

The mines and plant of the Superior Portland Cement Company are located along the valley of a small eastern tributary of Bear Run in the southwest quarter of Section 32, Decatur Township, about one-half mile northeast of Center Furnace. The Vanport limestone has been mined from a number of openings in this vicinity for the production of Portland cement. The strata exposed in the main air course, 1,200 feet from the new Belfonte opening, are described as follows:

		Ft.	In.
Iron ore, nodular, local, Ferriferous		-	3
Limestone, gray to light brown, somewhat ferruginous, Sample No. 417	Vanport	1	4
Limestone, gray to light brownish gray, hard, brittle, Sample No. 418	Vanport	5	8
Clay shale, bluish gray		-	6

Two samples of the Vanport limestone were secured from this mine by R. E. Lamborn on September 2, 1943, for chemical analysis. Sample No. 417 represents the top 1 foot 4 inches as described above whereas Sample No. 418 is of the bottom 5 feet 8 inches.

Samples No. 417, 418

Chemical analyses of Vanport limestone from mine of Superior Portland Cement Company, Section 32, Decatur Township, Lawrence County, E. Chadbourn, analyst

	Sample No. 417 Per cent	Sample No. 418 Per cent
Silica, SiO_2	1.36	0.66
Alumina, Al_2O_3	0.27	0.25
Ferric oxide, Fe_2O_3	0.04	0.00
Ferrous oxide, FeO	0.92	0.63
Iron disulphide, FeS_2	0.24	0.24
Magnesium oxide, MgO	0.32	0.37
Calcium oxide, CaO	53.43	54.01
Sodium oxide, Na_2O	0.04	0.00
Potassium oxide, K_2O	0.06	0.01
Water, hydroscopic, H_2O-	0.08	0.04
Water, combined, H_2O+	0.21	0.29
Carbon dioxide, CO_2	42.45	42.70

Titanium dioxide, TiO_2	0.02	0.00
Phosphorus pentoxide, P_2O_5	0.19	0.10
Sulphur trioxide, SO_3	0.11	0.23
Manganous oxide, MnO	0.15	0.12
Total	99.89	99.65

The per cent of each of the probable mineral components in Sample No. 417 as computed (Lamborn) from the chemical analysis is as follows:

Silica and hydrated aluminum silicates of sodium and potassium	1.93
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.05
Ferrous carbonate, $FeO. CO_2$	1.48
Iron disulphide, FeS_2	0.24
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO. P_2O_5$	0.41
Calcium sulphate, $CaO. SO_3$	0.19
Calcium carbonate, $CaO. CO_2$	94.83
Magnesium carbonate, $MgO. CO_2$	0.67
Manganese carbonate, $MnO. CO_2$	0.24
Water, hydroscopic, H_2O-	0.08
Unbalanced components (excess CO_2)	-0.25
Total	99.89

The per cent of each of the mineral components in Sample No. 418 as computed (Lamborn) from the chemical analysis is given below.

Silica and hydrated aluminum silicates of sodium and potassium	1.00
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.00
Ferrous carbonate, $FeO. CO_2$	1.02
Iron disulphide, FeS_2	0.24
Titanium dioxide, TiO_2	0.00
Calcium phosphate, $3CaO. P_2O_5$	0.22
Calcium sulphate, $CaO. SO_3$	0.39
Calcium carbonate, $CaO. CO_2$	95.90
Magnesium carbonate, $MgO. CO_2$	0.77
Manganese carbonate, $MnO. CO_2$	0.19
Water, hydroscopic, H_2O-	0.04
Unbalanced components (excess CO_2)	-0.12
Total	99.65

The Southern Ohio Products Company operates a quarry in the Vanport limestone near Lawrence in Elizabeth Township. The quarry is located on the north side of the road in the west central part of Section 16, about five-eighths of a mile southeast of the village store. The limestone has normal characteristics for this region as described in the following record of exposures at the quarry.

		Ft.	In.
Coal, Lower Kittanning or No. 5, Reported thickness		2	10
Clay shale and covered		8	2
Shale, black, carbonaceous		-	7
Coal, impure,	Lawrence	-	4
Clay shale, black	Lawrence	-	9
Coal, bony	Lawrence	-	3
Clay, bluish gray, plastic	Lawrence	6	4

Clay, arenaceous	Lawrence (cont.)		3	2
Shale, weathered			2	0
Iron ore, Ferriferous			-	7
Limestone, gray to light brown, with some nodular flint, not sampled	Vanport		1	6
Limestone, gray, tough, compact, fossiliferous, sampled			4	8
Bottom of quarry.				

A sample of the lower 4 feet 8 inches of the Vanport limestone quarried here was secured on October 2, 1942, by R. E. Lamborn for chemical analysis.

Sample No. 400

Chemical analysis of Vanport limestone from quarry of Southern Ohio Products Company, Section 16, Elizabeth Township, Lawrence County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	0.81
Alumina, Al_2O_3	0.20
Ferric oxide, Fe_2O_3	0.24
Ferrous oxide, FeO	0.57
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.67
Calcium oxide, CaO	52.12
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.01
Potassium oxide, K_2O	0.04
Water, hydroscopic, H_2O-	0.03
Water, combined, H_2O+	1.75
Carbon dioxide, CO_2	43.42
Titanium dioxide, TiO_2	0.00
Phosphorus pentoxide, P_2O_5	0.08
Sulphur trioxide, SO_3	0.06
Manganous oxide, MnO	<0.01
Carbon, organic, C	0.13
Hydrogen, organic, H	0.02
Total	100.15

The per cent of each of the mineral components in the sample has been calculated (Lamborn) from the chemical analysis with results as follows:

Silica and hydrated aluminum silicates of sodium and potassium	2.77
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.28
Ferrous carbonate, $FeO.CO_2$	0.92
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.00
Calcium phosphate, $3CaO.P_2O_5$	0.17
Calcium sulphate, $CaO.SO_3$	0.10
Calcium carbonate, $CaO.CO_2$	92.78
Magnesium carbonate, $MgO.CO_2$	1.40

Water, hydroscopic, H_2O-	0.03
Organic matter	0.15
Unbalanced components, (deficiency, CO_2)	+1.55
Total	100.15

The mine of the Stewart Lime Company in the Vanport limestone is located along Cannons Creek at the junction of the public and private roads in the northwest quarter of Section 14, Elizabeth Township. Stone from this mine has been utilized for agricultural lime and for furnace flux. The exposures in the workings are described as follows.

	Ft.	In.
Sandstone, roof	-	-
Iron ore, Ferriferous	-	8
Limestone, gray, dense to crystalline, fossiliferous, one bed, Vanport	6	9
Clay, gray, arenaceous	-	6

A sample of the Vanport limestone from this mine was collected by R. E. Lamborn for chemical analysis on October 1, 1942.

Sample No. 399

Chemical analysis of Vanport limestone from mine of Stewart Lime Company, Section 14, Elizabeth Township, Lawrence County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	4.60
Alumina, Al_2O_3	0.19
Ferric oxide, Fe_2O_3	0.64
Ferrous oxide, FeO	1.93
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.77
Calcium oxide, CaO	48.21
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.03
Potassium oxide, K_2O	0.05
Water, hydroscopic, H_2O-	0.00
Water, combined, H_2O+	1.82
Carbon dioxide, CO_2	41.11
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.10
Sulphur trioxide, SO_3	0.21
Manganous oxide, MnO	0.01
Carbon, organic, C	0.19
Hydrogen, organic, H	0.05
Total	99.92

As computed (Lamborn) from the analysis the composition expressed in terms of the mineral components probably present in the sample is as follows:

Silica and hydrated aluminum silicates of sodium and potassium	6.58
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.75
Ferrous carbonate, $FeO.CO_2$	3.11
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.01
Calcium phosphate, $3CaO.P_2O_5$	0.22

Calcium sulphate, $CaO.SO_3$	0.36
Calcium carbonate, $CaO.CO_2$	85.57
Magnesium carbonate, $MgO.CO_2$	1.61
Manganese carbonate, $MnO.CO_2$	0.01
Water, hydroscopic, H_2O-	0.00
Organic matter	0.24
Unbalanced components (deficiency CO_2)	+1.46
Total	99.92

The Ferriferous ore being well exposed in the mine of the Stewart Lime Company was likewise sampled for chemical analysis on October 1, 1942.

Sample No. 407

Chemical analysis of Ferriferous ore from mine of Stewart Lime Company, Section 14, Elizabeth Township, Lawrence County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	1.54
Alumina, Al_2O_3	0.88
Ferric oxide, Fe_2O_3	1.51
Ferrous oxide, FeO	45.55
Iron disulphide, FeS_2	0.39
Magnesium oxide, MgO	0.96
Calcium oxide, CaO	9.43
Sodium oxide, Na_2O	0.03
Potassium oxide, K_2O	0.11
Water, hydroscopic, H_2O-	0.11
Water, combined, H_2O+	1.10
Carbon dioxide, CaO_2	36.37
Titanium dioxide, TiO_2	0.04
Phosphorus pentoxide, P_2O_5	0.52
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.91
Total	99.49

As calculated (Lamborn) from the chemical analysis the per cent of each of the mineral components in Sample No. 407 is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.30
$Al_2O_3.2SiO_2.2H_2O$	0.95
Silica, SiO_2	0.50
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	1.77
Ferrous carbonate, $FeO.CO_2$	73.43
Iron disulphide, FeS_2	0.39
Titanium dioxide, TiO_2	0.04
Calcium phosphate, $3CaO.P_2O_5$	1.13
Calcium sulphate, $CaO.SO_3$	0.07
Calcium carbonate, $CaO.CO_2$	15.68
Magnesium carbonate, $MgO.CO_2$	2.01
Manganese carbonate, $MnO.CO_2$	1.47
Water, hydroscopic, H_2O-	0.11
Unbalanced components, (deficiency CO_2, H_2O)	+0.64
Total	99.49

Lower Freeport Limestone

The Lower Freeport limestone is either wanting or very poorly represented in Lawrence County. Over small areas in Hamilton, Upper, and Elizabeth townships a calcareous, yellow kidney ore is found close below the Lower Freeport coal which probably represents a depositional phase of this limestone. It has no value for its lime content.

Upper Freeport Limestone

The Upper Freeport limestone is either wanting in this county or is represented by small inconspicuous limestone nodules embedded in Upper Freeport clay.

Brush Creek Member

The distribution of the Brush Creek member at the surface in Lawrence County is confined for the most part to the high hills and ridges east of Pine Creek, Storms Creek, and Cannons Creek, and north of Aaron Creek, including northwestern Elizabeth, eastern Decatur, and western Aid townships, and Symmes Township. It is likewise well developed on the outcrop east of Symmes Creek in the northwestern part of Mason Township. South of Aaron Creek in Aid Township the horizon of the Brush Creek is generally occupied by sandstone. The stratigraphic position and character of the Brush Creek beds in Lawrence County are described by Wilber Stout as follows: [1]

"This limestone, when present, is found usually from 80 to 90 feet above the Upper Freeport coal and from 20 to 30 feet below the Cambridge limestone. In parts of Gallia County, where characteristically developed, there are two beds of this member, which are separated by 15 to 20 feet of shale. As the Brush Creek limestone extends southward into Lawrence County the separate limestone beds become less distinct, and the whole interval in places is taken by thin layers of flinty limestone interbedded with shales."

The Brush Creek limestone has been quarried at a few localities in Symmes, Mason, and Decatur townships and utilized in road construction.

A quarry for the production of road stone has been operated in the Brush Creek limestone at the south central edge of Section 25, Decatur Township. The quarry is located on the north side of the road near the crest of the divide between the headwaters of Pine Creek and Slab Fork of Johns Creek. A description of the exposures is as follows:

	Ft.	In.
Limestone, flinty	-	6
Clay shale	-	1
Limestone, flinty	-	6
Clay shale	-	1
Limestone, cherty, nodular	-	2
Clay shale	-	1
Limestone	-	3
Shale, calcareous	-	2
Limestone	-	6
Clay shale	-	1
Limestone	-	3
Shale	-	2
Limestone	-	4
Clay shale	-	2

[1] *Op. cit., p. 414.*

Limestone	2	4
Clay shale	-	2
Limestone	-	5

A sample of the Brush Creek limestone exposed here was taken by Mr. Julian Maxey on September 22, 1939, and was analyzed by Downs Schaaf.

Sample No. 235

Chemical analysis of Brush Creek limestone from quarry located in Section 25, Decatur Township, Lawrence County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	51.20
Alumina, Al_2O_3	4.60
Ferric oxide, Fe_2O_3	0.77
Ferrous oxide, FeO	1.07
Iron disulphide, FeS_2	0.20
Magnesium oxide, MgO	0.75
Calcium oxide, CaO	20.71
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.10
Potassium oxide, K_2O	0.74
Water, hydroscopic, H_2O-	0.97
Water, combined, H_2O+	1.06
Carbon dioxide, CO_2	17.30
Titanium dioxide, TiO_2	0.14
Phosphorus pentoxide, P_2O_5	0.25
Sulphur trioxide, SO_3	0.02
Manganous oxide, MnO	0.15
Carbon, organic, C	0.04
Hydrogen, organic, H	--
Total	100.07

The per cent of each of the compounds probably present in Sample No. 235 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	7.49
Silicates $Al_2O_3.2SiO_2.2H_2O$	4.31
Silica, SiO_2	45.78
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.90
Ferrous carbonate, $FeO.CO_2$	1.73
Iron disulphide, FeS_2	0.20
Titanium dioxide, TiO_2	0.14
Calcium phosphate, $3CaO.P_2O_5$	0.55
Calcium sulphate, $CaO.SO_3$	0.03
Calcium carbonate, $CaO.CO_2$	36.41
Magnesium carbonate, $MgO.CO_2$	1.57
Manganese carbonate, $MnO.CO_2$	0.24
Water, hydroscopic, H_2O-	0.97
Organic matter	0.04
Unbalanced components (excess CO_2, H_2O)	-0.29
Total	100.07

The Brush Creek limestone occurs in good development near Arabia, Mason Township, where it has been quarried by the State Highway Department and utilized in road construction and repair. The quarry is located along the north side of a small valley tributary to Symmes Creek about one-half mile northeast of Arabia in the south central part of Section 6. The exposures are described by Julian Maxey as follows: [1]

	Ft.	In.
Limestone, dense, cherty	-	9
Shale	-	1 1/2
Limestone, dense, cherty	1	4
Limestone, shaly	-	3
Shale	-	1/2
Limestone, cherty	-	7 1/2
Shale	-	3 1/2
Limestone, cherty		8
Shale	-	3 1/2
Limestone, cherty	-	3 1/2
Shale	-	3
Limestone, cherty	-	8
Shale	-	4
Limestone, cherty	-	2
Shale	-	2 1/2
Limestone, cherty	1	1
Limestone, cherty	1	-
Bottom of quarry.		

A sample of the Brush Creek beds as described above, including both the cherty limestone and the calcareous shale partings, was secured by Julian Maxey on September 8, 1939, and was analyzed by the Geological Survey.

Sample No. 233

Chemical analysis of Brush Creek beds from State Quarry, Section 6, Mason Township, Lawrence County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	52.75
Alumina, Al_2O_3	6.28
Ferric oxide, Fe_2O_3	0.59
Ferrous oxide, FeO	1.01
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.92
Calcium oxide, CaO	18.60
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.12
Potassium oxide, K_2O	0.95
Water, hydroscopic, H_2O-	1.11
Water, combined, H_2O+	1.46
Carbon dioxide, CO_2	15.51
Titanium dioxide, TiO_2	0.22
Phosphorus pentoxide, P_2O_5	0.32
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.18
Carbon, organic, C	0.05
Hydrogen, organic, H	--
Total	100.11

[1] *Maxey, Julian S., Geology of a portion of Lawrence County, Ohio: a thesis presented for degree of Master of Science, Ohio State Univ., p. 39, 1940.*

The per cent of each of the various compounds probably present in Sample No. 233 has been calculated (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	9.51
Silicates $Al_2O_3.2SiO_2.2H_2O$	6.59
Silica, SiO_2	45.35
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.69
Ferrous carbonate, $FeO.CO_2$	1.63
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.22
Calcium phosphate, $3CaO.P_2O_5$	0.70
Calcium sulphate, $CaO.SO_3$	0.07
Calcium carbonate, $CaO.CO_2$	32.47
Magnesium carbonate, $MgO.CO_2$	1.92
Manganese carbonate, $MnO.CO_2$	0.29
Water, hydroscopic, H_2O-	1.11
Organic matter	0.05
Unbalanced components (excess CO_2, H_2O)	-0.49
Total	100.11

Cambridge Limestone

The distribution and character of the Cambridge limestone in Lawrence County are described by Wilber Stout as follows: [1]

"The Cambridge limestone is found over a wide area in Lawrence County, extending in a belt about 10 miles wide from the Ohio River to the northern boundary. Its western limit is practically the ridges that form the divide between the Symmes Creek and Pine and Storms creeks basins from the northern boundary of the county to Kitts Hill, then south from this point to Coal Grove. Its eastern boundary is close to Symmes Creek, from near its mouth to as far north as Willowood, then northward to the heads of Long and Buck creeks and to the Lawrence-Gallia line, which there forms the boundary. The average thickness of this limestone is between 3 and 4 feet, with a maximum of 6 to 7 feet. It is best developed in the region extending from Marion Township, and from the head of Long Creek in Aid and Mason townships, northward to Arabia, thence across the ridge between Aaron and Johns creeks to the ridge between Johns and Buffalo creeks in Symmes Township north of Sherritts. In this area the limestone usually is from 4 to 6 feet in thickness. The Cambridge limestone in Lawrence County is generally quite siliceous, which restricts it to a few uses; the most important of these are for road ballast and concrete work, for which it is largely used in the Symmes Creek Valley, where the higher grade Ferriferous limestone is less available."

The Cambridge limestone was formerly well exposed just above an old mine in the Wilgus coal located on the O. E. Irish and E. L. Riley property in Section 19, Symmes Township. The old mine is located south of the divide near its summit in the east central part of the northwest quarter of the section. A description of the exposures as noted by Julian Maxey follows:

		Ft.	In.
Limestone, gray fossiliferous	Cambridge	-	10
Limestone, flinty	Cambridge	-	1

[1] *Op. cit., p. 423, 1916.*

			Ft.	In.
Limestone, gray, flinty	Cambridge (cont.)		4	0
Limestone, gray, flinty			-	10
Shale			-	1
Limestone, shaly			-	4
Shale			-	2
Limestone, gray, fossiliferous			1	8
"Draw slate"			-	1 1/2
Coal, without partings, Wilgus			3	0

The Cambridge member having a thickness of 8 feet was sampled at this locality by Julian Maxey on September 8, 1939.

Sample No. 232

Chemical analysis of Cambridge limestone from outcrop, Section 19, Symmes Township, Lawrence County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	32.55
Alumina, Al_2O_3	2.41
Ferric oxide, Fe_2O_3	0.48
Ferrous oxide, FeO	0.68
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.79
Calcium oxide, CaO	33.51
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.01
Potassium oxide, K_2O	0.02
Water, hydroscopic, H_2O-	0.60
Water, combined, H_2O+	0.72
Carbon dioxide, CO_2	27.40
Titanium dioxide, TiO_2	0.16
Phosphorus pentoxide, P_2O_5	0.29
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.34
Carbon, organic, C	0.07
Hydrogen, organic, H	--
Total	100.07

The per cent of each of the various compounds probably present in Sample No. 232 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.29
Silicates $Al_2O_3.2SiO_2.2H_2O$	5.81
Silica, SiO_2	29.71
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.56
Ferrous carbonate, $FeO.CO_2$	1.10
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.16
Calcium phosphate, $3CaO.P_2O_5$	0.63
Calcium sulphate, $CaO.SO_3$	0.07
Calcium carbonate, $CaO.CO_2$	59.15
Magnesium carbonate, $MgO.CO_2$	1.65
Manganese carbonate, $MnO.CO_2$	0.55

Water, hydroscopic, H_2O-	0.60
Organic matter	0.07
Unbalanced components (excess CO_2, H_2O)	-0.28
Total	100.07

The Cambridge limestone is well exposed in an old quarry located about five-eighths of a mile southeast of Arabia in the southwest part of the northwest quarter of the southeast quarter of Section 7, Mason Township. The total thickness of the limestone exposure excluding thin shale partings is 4 feet 4 inches. As described by Julian Maxey the succession is as follows:

		Ft.	In.
Shale, bluish gray	Cambridge	3	10
Limestone, gray, somewhat fossiliferous, one bed		1	8
Clay shale		-	2
Limestone, gray, fossiliferous, one bed		1	8
Clay shale		-	2 1/2
Limestone, flinty		-	2
Clay		-	2
Limestone, gray, fossiliferous, one bed		1	5

The Cambridge member as described above was sampled by Mr. Maxey on September 21, 1939, for chemical analysis. The sample was analyzed by Downs Schaaf of the Geological Survey.

Sample No. 234

Chemical analysis of Cambridge limestone from old quarry, Section 7, Mason Township, Lawrence County, Downs Schaaf, analyst

Silica, SiO_2	23.50
Alumina, Al_2O_3	1.83
Ferric oxide, Fe_2O_3	0.35
Ferrous oxide, FeO	0.72
Iron disulphide, FeS_2	0.65
Magnesium oxide, MgO	0.90
Calcium oxide, CaO	38.55
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.07
Potassium oxide, K_2O	0.35
Water, hydroscopic, H_2O-	0.60
Water, combined, H_2O+	0.36
Carbon dioxide, CO_2	31.37
Titanium dioxide, TiO_2	0.06
Phosphorus pentoxide, P_2O_5	0.21
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.41
Carbon, organic, C	0.08

Hydrogen, organic, H	--
Total	100.05

The per cent of the various compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	3.82
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.88
Silica, SiO_2	21.35
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.41
Ferrous carbonate, $FeO.CO_2$	1.16
Iron disulphide, FeS_2	0.65
Titanium dioxide, TiO_2	0.06
Calcium phosphate, $3CaO.P_2O_5$	0.46
Calcium sulphate, $CaO.SO_3$	0.07
Calcium carbonate, $CaO.CO_2$	68.31
Magnesium carbonate, $MgO.CO_2$	1.88
Manganese carbonate, $MnO.CO_2$	0.66
Water, hydroscopic, H_2O-	0.60
Organic matter	0.08
Unbalanced components (excess CO_2, H_2O)	-0.34
Total	100.05

Ames Limestone

The Ames limestone is generally wanting where due on the outcrop in Lawrence County, its place being occupied by red argillaceous shales. Thin nodular limestone measuring a few inches in thickness and therefore having trifling economic possibilities has been reported, however, at scattered localities along the ridges in eastern Lawrence and eastern Aid townships.

Elk Lick (?) Limestone

Closely overlying the Morgantown sandstone in the lower Symmes Creek Valley is a gray nodular non-fossiliferous limestone which occurs with some persistence. Thicknesses varying from 1 to 4 feet are reported, but the stone is rather arenaceous and impure.

LICKING COUNTY

General Considerations

Licking County, embracing an area of about 688 square miles, contains within its borders exposures of consolidated rocks of both the Pennsylvanian and Mississippian systems. Beds of Mississippian age either reach the surface or immediately underlie the glacial drift over about 93 per cent of the area of the county. These beds consist of sandstones, shales, and conglomerates of the Cuyahoga and Logan formations. The Maxville limestone, which in normal sequence overlies the Logan and which is the top formation of the Mississippian rock series in Ohio, has not been found on the outcrop in this county. All vestiges of the Maxville formation were removed by erosion before later series were deposited. Beds of Pennsylvanian age are confined in their distribution to the high hills, ridges, and uplands in the eastern third of the county including parts of Eden, Fallsbury, Mary Ann, Perry, Madison, Hanover, Franklin, Hopewell, and Bowling Green townships. The total maximum thickness of the Pennsylvanian beds exposed is approximately 200 feet. This thickness includes the Pottsville series and the lower part of the Allegheny series up to and including the Vanport member. The most important limestone members of the Pennsylvanian which are due to outcrop in this county are the Lower Mercer, Upper Mercer, Putnam Hill, and Vanport. Owing to the general presence of glacial drift, rock exposures are comparatively few in number and short in vertical extent.

Underlying the bedrocks exposed at the surface in Licking County is a series of shales with varying amounts of thin sandstone in the upper part which measures several hundreds of feet in thickness and which extends downward to the top of the Middle Devonian limestone. The upper surface of this limestone occurs about 200 feet above sea level in the northwestern corner of the county from where it slopes to the southeast, reaching a depth of 1,200 feet below sea level in the southeastern part of Hopewell Township.

Lower Mercer Limestone

The Lower Mercer limestone is due to reach the surface near the crests of the high ridges in central Fallsbury Township, in southeastern Hanover Township, and in central Hopewell Township. The best known development of this member in Licking County is found along Flint Ridge in Hopewell Township where at many places it measures 9 to 15 feet in thickness. Here it generally consists of a bottom heavy-bedded layer ranging from 1 to 2 feet in thickness capped by 7 to 10 feet of shaly limestone or thin-bedded limestone interstratified with thin argillaceous shales. The member has not been utilized for economic purposes in this county.

The shaly limestone phase of the Lower Mercer horizon is well developed near the head of Berry Run in the southwest part of Hopewell Township. The exposures occurring along the road three-fourths of a mile north of Hearst School are described as follows:

		Ft.	In.
Shale, dark and covered		5	0
Limestone, bluish gray, impure, shaly, fossiliferous	Lower Mercer	4	0
Limestone, bluish gray, fossiliferous, more heavily bedded	Lower Mercer	1	8
Shale		-	6

The Lower Mercer limestone member having a thickness of 5 feet 8 inches at this locality was sampled on June 29, 1944, by R. E. Lamborn for chemical analysis.

Sample No. 435

Chemical analysis of Lower Mercer limestone from outcrop, three-fourths of a mile north of Hearst School, Hopewell Township, Licking County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	30.46
Alumina, Al_2O_3	4.31
Ferric oxide, Fe_2O_3	0.49
Ferrous oxide, FeO	1.08
Iron disulphide, FeS_2	0.86
Magnesium oxide, MgO	0.90

Calcium oxide, CaO	32.45
Sodium oxide, Na_2O	0.14
Potassium oxide, K_2O	0.94
Water hydroscopic, H_2O-	0.34
Water, combined, H_2O+	1.46
Carbon dioxide, CO_2	25.74
Titanium dioxide, TiO_2	0.14
Phosphorus pentoxide, P_2O_5	0.23
Sulphur trioxide, SO_3	0.08
Manganous oxide, MnO	0.09
Total	99.71

The per cent of each of the various mineral components in Sample No. 435 as determined by calculation (Lamborn) from the chemical analysis is listed below.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	9.68
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.43
Silica, SiO_2	25.38
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.57
Ferrous carbonate, $FeO.CO_2$	1.74
Iron disulphide, FeS_2	0.86
Titanium dioxide, TiO_2	0.14
Calcium phosphate, $3CaO.P_2O_5$	0.50
Calcium sulphate, $CaO.SO_3$	0.14
Calcium carbonate, $CaO.CO_2$	57.33
Magnesium carbonate, $MgO.CO_2$	1.88
Manganese carbonate, $MnO.CO_2$	0.15
Water, hydroscopic, H_2O-	0.34
Unbalanced components (excess CO_2, H_2O)	-0.43
Total	99.71

Upper Mercer Limestone

The areal distribution of outcrops of the Upper Mercer limestone horizon is essentially the same as the Lower Mercer as its position is only 15 to 25 feet higher in the section. In Hopewell Township the Upper Mercer limestone is either wanting or is represented by a flinty bed ranging from a few inches to 2 feet in thickness.

Putnam Hill

The field of outcrop of the Putnam Hill limestone horizon in Licking County is confined chiefly to Flint Ridge and vicinity in Hopewell and southeastern Franklin townships. The limestone is very poorly represented in this area. Where present it generally measures a few inches in thickness but in many localities its horizon is occupied by sandstone.

Vanport Limestone

The Vanport member is well developed along Flint Ridge in Hopewell and southeastern Franklin townships. Here it is represented by a top bed of relatively pure flint measuring 5 feet or so in thickness underlain by several feet of strata which from place to place may consist of calcareous shale, shaly limestone, or flinty limestone. The shaly limestone phase in places reaches a thickness of 20 feet or more. The presence of the flint with its high weather resisting qualities has given name and topographic expression to Flint Ridge. The flint was worked extensively by the aborigines from many pits located along this ridge, was transported far overland, and was used for tools, weapons, and decorative purposes. In recent years it has been quarried on a small scale at one or two places along Flint Ridge, crushed, and utilized for sand blast purposes, and for the production of ferrosilicon.

For an analysis of the shaly limestone phase of the Vanport see sections of this report dealing with the outcrops in Muskingum County.

The following section was secured by Wilber Stout along the first ravine east of the north-south road, about one-fourth mile northeast of the crossroads on Flint Ridge, some 3 miles due north of Brownsville.

		Ft.	In.
Flint, variable	Vanport	6	0
Limestone, siliceous, fossiliferous	Vanport	7	0
Covered interval		32	0
Sandstone and covered		28	0
Sandstone, massive		4	0
Shale		1	0
Sandstone, massive		23	0
Shale, calcareous, fossiliferous	Lower Mercer	1	0
Limestone, dark, fossiliferous	Lower Mercer	-	8
Shale, dark, calcareous, fossiliferous	Lower Mercer	5	0
Limestone, hard, gray, fossiliferous	Lower Mercer	3	6
Shale, calcareous, fossiliferous		-	2
Coal, blocky, Middle Mercer		-	4
Clay, shaly		1	0

The Vanport flint measuring 6 feet at this locality was sampled in 1934 by Wilber Stout for chemical analysis.

Sample No. 83

Chemical analysis of Vanport flint from outcrop on Flint Ridge, 3 miles north of Brownsville, Hopewell Township, Licking County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	98.93
Alumina, Al_2O_3	0.14
Ferric oxide, Fe_2O_3	0.06
Ferrous oxide, FeO	0.08
Iron disulphide, FeS_2	none
Magnesium oxide, MgO	0.02
Calcium oxide, CaO	0.04
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	<0.01
Water, hydroscopic, H_2O-	0.27
Water, combined, H_2O+	0.17
Carbon dioxide, CO_2	0.02

Titanium dioxide, TiO_2	0.005
Phosphorus pentoxide, P_2O_5	<0.01
Sulphur trioxide, SO_3	none
Manganous oxide, MnO	<0.01
Carbon, organic, C	0.18
Total	99.915

LORAIN COUNTY

General Considerations

The bedrocks immediately underlying the surface deposits of glacial drift and lacustrine clays and sands in Lorain County consists of sedimentary types of clastic origin. Of these the Berea sandstone of Mississippian age has by far the most economic importance. Below this sandstone, shales belonging to the Bedford, Cleveland, and Chagrin subdivisions, and having a combined average thickness on outcrops of about 100 feet, extend to the level of the lake. In the southern part of the county the Berea sandstone is overlain by shales and thin sandstone of the Cuyahoga formation having a maximum thickness, as indicated by well records, close to 400 feet. No limestone beds occur in this formation. The limestones and dolomites of Silurian and Devonian ages, which reach the surface in the western half of Ohio, dip in an eastern direction beneath the beds described above, and are reached in Lorain County at depths below sea level ranging from zero feet near Amherst, Amherst Township, to approximately 550 feet in eastern Columbia Township.

MAHONING COUNTY

General Considerations

Mahoning County embraces an area of about 425 square miles located in the glaciated portion of the Allegheny Plateau of northeastern Ohio. The land surface in this county is a rolling upland whose surface deposits are composed in large part of glacial drift of variable character and thickness. Bedrock exposures are few in number and are confined for the most part to slopes bordering the deeper valleys. The bedrocks immediately underlying the glacial drift represent series belonging to the Pennsylvanian and Mississippian systems. Outcrops of sandstones and shales of the Mississippian are confined to the narrow areas bordering the Mahoning River in Poland, southwestern Coitsville, and central Youngstown townships and to small areas along Meander Creek in northeastern Jackson and northwestern Austintown townships. Above the Mississippian beds and underlying all the higher hills and uplands in the county are the sandstones, shales, coals, clays, and limestones representing the Pottsville and Allegheny series of the Pennsylvanian. As the direction of maximum dip or slope of the beds is a little east of south in this part of Ohio, outcrops of the Allegheny or youngest series are confined to the southern part. The total vertical thickness of the strata outcropping across Mahoning County is approximately 625 feet.

The limestones which reach the surface in Mahoning County and which have been recognized at several small scattered exposures are confined in vertical scale to the Allegheny and Pottsville and in distribution chiefly to the southern two-thirds of the county. Small quarries have operated in these limestones in Berlin, Smith, and Ellsworth townships but the thickest deposits and the largest operations are found in Poland and Coitsville townships in the eastern part. The limestone members exposed in Mahoning County in descending order are as follows:

Hamden limestone
Vanport limestone
Upper Mercer limestone
Lower Mercer limestone
Lowellville limestone

In drilling wells for oil and gas no limestones are encountered by the drill below the Pennsylvanian beds until the Middle Devonian is reached at depths below sea level ranging from 1,800 feet in the northwest corner to 2,500 feet in the southeast corner of the county.

Lowellville Limestone

The Lowellville limestone was first named by G. F. Lamb in 1910 for exposures near Lowellville, Mahoning County. [1] In 1922 it was correlated by Morningstar [2] with the Poverty Run limestone of Muskingum County described by Stout in 1918 [3]. In Mahoning County the known distribution of this limestone is confined to the Mahoning Valley at Lowellville. As described by Lamb, along Grindstone Run "the limestone is black, very hard, tough, and apparently in one layer. It is 2 feet or more in thickness." [4] The exposures along Grindstone Run were described in part by Lamborn in 1919 as follows:

	Ft.	In.
Limestone, Upper Mercer	2	0
Covered interval	3	0
Clay	1	0
Covered interval	9	0
Sandstone and shale, sandy	5	0
Shale	5	0
Ore, nodular, Lower Mercer	--	4
Limestone (Lower Mercer)	2	1
Limestone, very fossiliferous (Lower Mercer)	--	5
Shale, black	--	4
Shale, gray, argillaceous	2	8
Coal, bony	--	2
Clay, bluish gray, flinty	4	0
Shale, gray, siliceous	3	6
Covered interval	5	0
Shale, gray, siliceous	6	0
Shale, bluish gray	3	6
Covered interval	30	0
Sandstone, thin-bedded	6	0
Shale, arenaceous, ferruginous	28	6
Shale, black, fissile, calcareous	2	4
Limestone, Lowellville	2	0

The 2-foot bed of Lowellville limestone exposed along Grindstone Run was sampled by R. E. Lamborn on July 14, 1943, for chemical analysis.

Sample No. 409

Chemical analysis of Lowellville limestone from Grindstone Run, Poland Township, Mahoning County, E. Chadbourn, analyst

[1] *Lamb, G. F., Pennsylvanian limestones of northeastern Ohio below the Lower Kittanning coal: Ohio Naturalist, Vol. 10. pp. 128-129, 1910.*

[2] *Morningstar, Helen, Pottsville fauna of Ohio: Geol. Survey Ohio Bull. 25, p. 28, 1922.*

[3] *Stout, Wilber, Geology of Muskingum County: Geol. Survey Ohio Bull. 21, p. 65, 1918.*

[4] *Op. cit., p. 128.*

	Per cent
Silica, SiO_2	19.68
Alumina, Al_2O_3	5.90
Ferric oxide, Fe_2O_3	0.31
Ferrous oxide, FeO	1.35
Iron disulphide, FeS_2	2.36
Magnesium oxide, MgO	0.99
Calcium oxide, CaO	35.50
Sodium oxide, Na_2O	0.12
Potassium oxide, K_2O	0.96
Water, hydroscopic, H_2O-	0.18
Water, combined, H_2O+	1.94
Carbon dioxide, CO_2	28.54
Titanium dioxide, TiO_2	0.32
Phosphorus pentoxide, P_2O_5	0.38
Sulphur trioxide, SO_3	0.24
Manganous oxide, MnO	0.25
Total	99.02

The per cent of each of the mineral components in Sample No. 409 has been computed (Lamborn) from the chemical analysis and is listed below.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	9.60
Silicates $Al_2O_3.2SiO_2.2H_2O$	5.54
Silica, SiO_2	12.73
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.36
Ferrous carbonate, $FeO.CO_2$	2.18
Iron disulphide, FeS_2	2.36
Titanium dioxide, TiO_2	0.32
Calcium phosphate, $3CaO.P_2O_5$	0.83
Calcium sulphate, $CaO.SO_3$	0.41
Calcium carbonate, $CaO.CO_2$	62.26
Magnesium carbonate, $MgO.CO_2$	2.07
Manganese carbonate, $MnO.CO_2$	0.40
Water, hydroscopic, H_2O-	0.18
Unbalanced components (excess CO_2, H_2O)	-0.22
Total	99.02

Lower Mercer Limestone

The Lower Mercer limestone occurs above drainage across a broad east-west belt of territory embracing all or parts of Milton, Berlin, Jackson, Ellsworth, Austintown, Canfield, Boardman, Youngstown, Poland, and Coitsville townships. The covering of glacial drift in this area, however, permits few rock exposures. The limestone is known to outcrop along Mill Creek in southwestern Berlin Township, at a few localities along the valley of Meander Creek in Ellsworth Township, and along the valleys tributary to the Mahoning from Youngstown southeast to the State line. In these areas the Lower Mercer is a dark bluish gray dense limestone usually occurring in one or two layers and having a total thickness varying from 2 to 3 feet. A thin nodular iron ore is found in places immediately overlying the limestone.

The Lower Mercer limestone as well as overlying and underlying beds outcrops along Mill Creek in Berlin Township about 2 1/2 miles northeast of North Benton. The exposures were measured and described by the writer in 1919 as follows:

		Ft.	In.
Limestone, Upper Mercer		3	4
Covered interval		5	4
Shale, black		2	0
Coal, Upper Mercer or 3b		--	10
Shale, black, carbonaceous		--	7
Clay		5	0
Shale, gray		1	0
Sandstone, shaly		5	4
Shale, gray, sandy		7	6
Limestone, hard, fossiliferous	Lower Mercer	2	0
Limestone, very fossiliferous	Lower Mercer	--	6
Clay shale		--	1
Coal, Middle Mercer		--	2
Clay shale, gray		1	0
Covered		2	0
Clay shale, bluish gray		1	0
Sandstone, shaly, micaceous		2	0

Just south of Mill Creek and about three-eighths of a mile below the mouth of Turkeybroth Creek the Lower Mercer limestone has been quarried in a small way for agricultural use. The exposures are described as follows:

		Ft.	In.
Glacial drift		2	0
Limestone, bluish gray, dense, tough, one layer	Lower Mercer	2	2
Limestone, bluish gray, one layer	Lower Mercer	--	7
Shale, dark		--	6
Clay, bluish gray, plastic		4	6

On May 6, 1941, a sample was secured at this locality by R. E. Lamborn for chemical analysis.

Sample No. 324

Chemical analysis of Lower Mercer limestone along Mill Creek, 2 miles northeast of North Benton, Berlin Township, Mahoning County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	1.77
Alumina, Al_2O_3	1.14
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	1.07
Iron disulphide, FeS_2	0.61
Magnesium oxide, MgO	1.01
Calcium oxide, CaO	51.28
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.05
Water, hydroscopic, H_2O-	0.16

Water, combined, H_2O+	0.33
Carbon dioxide, CO_2	41.81
Titanium dioxide, TiO_2	0.06
Phosphorus pentoxide, P_2O_5	0.18
Sulphur trioxide, SO_3	0.11
Manganous oxide, MnO	0.14
Carbon, organic, C	0.25
Hydrogen, organic, H	0.02
Total	100.04

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.67
Hydrated silicates $Al_2O_3.2Al_2O_3.2H_2O$	2.22
Silica, SiO_2	0.43
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	1.72
Iron disulphide, FeS_2	0.61
Titanium dioxide, TiO_2	0.06
Calcium phosphate, $3CaO.P_2O_5$	0.39
Calcium sulphate, $CaO.SO_3$	0.18
Calcium carbonate, $CaO.CO_2$	91.01
Magnesium carbonate, $MgO.CO_2$	2.11
Manganese carbonate, $MnO.CO_2$	0.23
Water, hydroscopic, H_2O-	0.16
Organic matter	0.27
Unbalanced components (excess CO_2, H_2O)	-0.06
Total	100.04

On the J. L. Harding property, located about 1 1/4 miles northeast of Ellsworth, the Lower Mercer limestone, 3 feet in thickness, was formerly worked in a very small way for agricultural use. This limestone is generally well exposed at an elevation of about 1,000 feet in ravines tributary to the Mahoning Valley in the vicinity of Lowellville. It is likewise well exposed in the bed of Yellow Creek at Poland, Poland Township, where the following observations were made:

		Ft.	In.
Sandstone, cross-bedded		10	0
Shale, dark, calcareous, many ore nodules		--	8
Limestone, dark bluish gray to black, dense, tough	Lower Mercer	2	2
Limestone, dark, tough, platy	Lower Mercer	--	5 1/2
Shale, dark, calcareous, fossiliferous		--	6
Shale, black, fissile		--	5
Clay, dark		1	0

The Lower Mercer limestone, 2 feet 7 1/2 inches in thickness, was sampled at this locality by R. E. Lamborn on May 7, 1941, for chemical analysis.

Sample No. 328

Chemical analysis of Lower Mercer limestone from outcrops at Poland, Poland Township, Mahoning County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	3.27
Alumina, Al_2O_3	1.47
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	1.17
Iron disulphide, FeS_2	0.32
Magnesium oxide, MgO	0.90
Calcium oxide, CaO	50.27
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.04
Water, hydroscopic, H_2O-	0.10
Water, combined, H_2O+	0.42
Carbon dioxide, CO_2	40.91
Titanium dioxide, TiO_2	0.07
Phosphorus pentoxide, P_2O_5	0.28
Sulphur trioxide, SO_3	0.05
Manganous oxide, MnO	0.14
Carbon, organic, C	0.44
Hydrogen, organic, H	0.04
Total	99.94

Expressed as mineral compounds, the percent of each having been computed (Lamborn) from the chemical analysis, the composition of Sample No. 328 is as follows:

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.58
Hydrated silicates $Al_2O_3.2SiO_2.2H_2O$	3.14
Silica, SiO_2	1.54
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	1.89
Iron disulphide, FeS_2	0.32
Titanium dioxide, TiO_2	0.07
Calcium phosphate, $3CaO.P_2O_5$	0.61
Calcium sulphate, $CaO.SO_3$	0.08
Calcium carbonate, $CaO.CO_2$	89.07
Magnesium carbonate, $MgO.CO_2$	1.88
Manganous carbonate, $MnO.CO_2$	0.23
Water, hydroscopic, H_2O-	0.10
Organic matter	0.48
Unbalanced components (excess CO_2, H_2O)	-0.09
Total	99.94

Upper Mercer Limestone

The areal distribution of the Upper Mercer limestone horizon in this county is essentially the same as the Lower Mercer above which it occurs with intervals varying from 20 to 30 feet. Glacial drift deposits present few exposures. Where the drift has been removed by erosion, exposing the bedrocks to view, this limestone may be thin and nodular, may be a regularly bedded member measuring 3 feet or so in thickness, or its horizon may be entirely replaced by sandstone and shale. Black nodular flint which is invariably present on Upper Mercer limestone horizon in the Tuscarawas Valley is not such a conspicuous element of the member in Mahoning County. To the writer's knowledge, the Upper Mercer limestone is not being utilized in Mahoning County, and as a potential resource its value is very small.

Vanport Limestone

Outcrops of the Vanport limestone horizon are due above drainage over a broad belt extending across Mahoning County from Smith Township on the southwest to Poland and Coitsville townships on the east. Glacial drift deposits have so covered the bedrock that little is known concerning this limestone except in Poland and Coitsville townships where it occurs near the hilltops at altitudes of 1,100 feet or more. Limestone described as Vanport was formerly worked on a small scale a short distance east of Best Station in Section 9, Smith Township. [1] Near Lowellville in Poland and Coitsville townships the Vanport has been quarried for many years for furnace flux, for agricultural lime, and for road material. Here the limestone is generally light to dark brown in color, dense and compact in structure, and highly fossiliferous. The upper part of the member is generally heavy bedded whereas the beds in the lower part tend to be thin and nodular in character and are separated by thin shale partings. The total thickness of the limestone in this part of the county is approximately 20 feet.

The Carbon Limestone Company operates a quarry in the Vanport limestone near the Kansas School about 4 miles southeast of Poland. The drift and shales are removed by stripping, the limestone is quarried by mechanical methods, and the stone is marketed for furnace flux and for agricultural limestone. The beds exposed in the quarry are described as follows:

		Ft.	In.
Glacial drift		10	0
Shale, bluish in color		20	0
Limestone, light brown. Beds vary from 2 inches to 2 feet in thickness	Vanport	12	4
Limestone, brown, nodular	Vanport	5	10
Limestone, brown, dense, hard	Vanport	1	6
Bottom of pit.			

The 19 feet 8 inches of Vanport limestone exposed in this quarry was sampled for chemical analysis by R. E. Lamborn on May 6, 1941.

Sample No. 325

Chemical analysis of Vanport limestone from quarry of the Carbon Limestone Company, Poland Township, Mahoning County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	2.40
Alumina, Al_2O_3	0.40
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.55
Iron disulphide, FeS_2	0.03
Magnesium oxide, MgO	0.53
Calcium oxide, CaO	52.92
Strontium oxide, SrO	<0.01

[1] *Lamb, G. F., Pennsylvanian limestones of northeastern Ohio below the Lower Kittanning coal: Ohio Naturalist, Vol. 10, p. 89, 1910.*

Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.01
Potassium oxide, K_2O	0.02
Water, hydroscopic, H_2O-	0.12
Water, combined, H_2O+	0.10
Carbon dioxide, CO_2	42.31
Titanium dioxide, TiO_2	0.03
Phosphorus pentoxide, P_2O_5	0.16
Sulphur trioxide, SO_3	0.07
Manganous oxide, MnO	0.12
Carbon, organic, C	0.21
Hydrogen, organic, H	0.02
Total	100.02

The per cent of each of the compounds probably present in Sample No. 325 has been computed (Lamborn) from the chemical analysis.

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.29
Hydrated silicates $Al_2O_3.2SiO_2.2H_2O$	0.72
Silica, SiO_2	1.93
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	0.89
Iron disulphide, FeS_2	0.03
Titanium dioxide, TiO_2	0.03
Calcium phosphate, $3CaO.P_2O_5$	0.35
Calcium sulphate, $CaO.SO_3$	0.12
Calcium carbonate, $CaO.CO_2$	94.03
Magnesium carbonate, $MgO.CO_2$	1.11
Manganous carbonate, $MnO.CO_2$	0.19
Water, hydroscopic, H_2O-	0.12
Organic matter	0.23
Unbalanced components (excess CO_2, H_2O)	-0.04
Total	100.02

The Vanport limestone was formerly quarried by the Carbon Limestone Company near the State line about seven-eighths of a mile east of Lowellville. A description of the limestone exposures in this quarry is as follows:

		Ft.	In.
Limestone, brown, dense, tough, one layer	Vanport	2	0
Limestone, brown, dense, tough, one layer	Vanport	3	0
Limestone, nodular, thin-bedded	Vanport	8	0
Water level in quarry.			

Two samples of limestone were collected by R. E. Lamborn on May 7, 1941, for chemical analysis. Sample No. 326 represents the lower 8 feet of the exposure whereas Sample No. 327 portrays the character of the upper 5 feet as described in the section above.

Sample Nos. 326, 327

Chemical analyses of Vanport limestone from quarry of The Carbon Limestone Company near Lowellville, Poland Township, Mahoning County, Downs Schaaf, analyst

	Sample No. 326. Lower 8 feet Per cent	Sample No. 327. Upper 5 feet Per cent
Silica, SiO_2	3.11	2.28
Alumina, Al_2O_3	0.75	0.36
Ferric oxide, Fe_2O_3	0.02	0.03
Ferrous oxide, FeO	0.60	0.64
Iron disulphide, FeS_2	0.04	0.08
Magnesium oxide, MgO	0.65	0.60
Calcium oxide, CaO	52.10	53.03
Strontium oxide, SrO	<0.01	<0.01
Barium oxide, BaO	<0.01	<0.01
Sodium oxide, Na_2O	<0.01	<0.01
Potassium oxide, K_2O	0.01	0.02
Water, hydroscopic, H_2O-	0.10	0.08
Water, combined, H_2O+	0.20	0.09
Carbon dioxide, CO_2	41.82	42.59
Titanium dioxide, TiO_2	0.06	0.03
Phosphorus pentoxide, P_2O_5	0.14	0.11
Sulphur trioxide, SO_3	0.08	0.03
Manganous oxide, MnO	0.10	0.10
Carbon, organic, C	0.24	0.02
Hydrogen, organic, H	0.02	--
Total	100.04	100.09

The per cent of each of the compounds present in Sample No. 326 has been computed (Lamborn) from the analysis with results as follows:

	Per cent
Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.08
Hydrated silicates $Al_2O_3.2SiO_2.2H_2O$	1.82
Silica, SiO_2	2.23
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	0.97
Iron disulphide, FeS_2	0.04
Titanium dioxide, TiO_2	0.06
Calcium phosphate, $3CaO.P_2O_5$	0.31
Calcium sulphate, $CaO.SO_3$	0.14
Calcium carbonate, $CaO.CO_2$	92.59
Magnesium carbonate, $MgO.CO_2$	1.36
Manganese carbonate, $MnO.CO_2$	0.16
Water, hydroscopic, H_2O-	0.10
Organic matter	0.26
Unbalanced components (excess CO_2, H_2O)	-0.10
Total	100.04

The per cent of each of the various compounds probably present in Sample No. 327 has been computed (Lamborn) from the chemical analysis.

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.17
Hydrated silicates $Al_2O_3.2SiO_2.2H_2O$	0.75
Silica, SiO_2	1.85
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	1.03
Iron disulphide, FeS_2	0.08
Titanium dioxide, TiO_2	0.03
Calcium phosphate, $3CaO.P_2O_5$	0.24

Calcium sulphate, $CaO.SO_3$	0.05
Calcium carbonate, $CaO.CO_2$	94.38
Magnesium carbonate, $MgO.CO_2$	1.25
Manganese carbonate, $MnO.CO_2$	0.16
Water, hydroscopic, H_2O-	0.08
Organic matter	0.02
Unbalanced components (excess CO_2, H_2O)	-0.04
Total	100.09

Hamden Limestone

In Mahoning County outcrops of the Hamden member, which closely overlies the Lower Kittanning or No. 5 coal, are confined chiefly to Green, Beaver, and Springfield townships. In this field the Hamden consists chiefly of dark fossiliferous shale with occasional nodules of impure fossiliferous limestone embedded in it. No economic interest is attached to this member in Mahoning County.

MEDINA COUNTY

General Considerations

No limestone beds of economic importance crop out in Medina County. The stratified rocks which reach the surface where stream erosion has removed the glacial drift consist chiefly of sandstone, shale, and conglomerate belonging in large part to the Waverly group of the Mississippian system. In the eastern half of the county the chief divides and highlands are capped by beds of Pottsville age 100 feet or so in thickness. The Maxville limestone, which in some area in Ohio is found immediately underlying the Pottsville series, is wanting in Medina County. Below drainage level the Middle Devonian limestone is reached in wells at depths below sea level ranging from about 330 feet in northwestern Spencer Township to approximately 1,100 feet in southeastern Wadsworth Township.

MEIGS COUNTY

General Considerations

An exceptionally long and variable sedimentary series reaches the surface in Meigs County. The inferior limit is marked by outcrops of Middle Kittanning coal along Raccoon Creek in northwestern Columbia Township whereas the top of the series exposed forms the crests of the highest hills and ridges in Olive, Lebanon, and Letart townships in the eastern part of the county and occurs some 300 feet above the base of the Permian system. The vertical thickness of the series exposed across the county is approximately 1,000 feet. The character of the beds ranges from thin limestones of fair purity and local development to massive coarse-grained sandstones of broad extent. Red clays and red and gray clay shales are well exposed on the outcrop. The limestone members represented in exposures are confined chiefly to the Conemaugh and to a less extent to the Monongahela series, both of which outcrop as north-south belts across the western two-thirds of the area.

The succession and average thickness of members represented on the outcrop in Meigs County are shown in the following generalized section compiled from various sources [1].

Generalized Section of Bedrocks Outcropping in Meigs County

	Ft.	In.
Permian system		
Washington series		
Shales, red to gray, with some sandstone beds. Member not differentiated	170	0
Sandstone, Lower Marietta	26	0
Coal, thin, local, Washington	-	6
Shale and sandstone	60	0
Coal and black shale, local, Waynesburg A	2	6
Shale	7	8
Sandstone, Waynesburg	34	0
Pennsylvanian system		
Monongahela series		
Coal and carbonaceous shale, Waynesburg	-	2
Shale, soft, argillaceous, light gray	1	0
Shale and shaly sandstone, gray	9	5
Coal and bone shale, Little Waynesburg	-	1
Clay shale, drab, grainy	10	6
Clay shale, red, calcareous	12	0
Shale and shaly sandstone, gray	24	10
Coal and bone shale, Uniontown or No. 10	-	2
Clay shale, red, calcareous, with occasional thin limestone layers	41	0
Shale, and shaly sandstone, gray, Fulton horizon	18	0
Clay shale, red, calcareous, with some thin and marly limestone, Benwood	21	9
Sandstone, massive to shaly	20	0
Coal, Sewickley in many places replaced by sandstone	-	3
Sandstone, massive, with some shales locally	22	10
Coal and bone shale, usually replaced by sandstone, Fishpot	-	2
Sandstone, massive	30	1
Shale, gray, siliceous	3	5
Coal and partings, Redstone, Pomeroy, or 8a	2	10
Clay shale, calcareous, with local deposits of thin limestone, Redstone	3	6
Shale, with sandstone lenses	21	5
Coal and parting, Pittsburgh or No. 8	2	4
Conemaugh series		
Limestone, nodular, or in layers interlain with clay, Pittsburgh	4	0
Shale, sandy	45	0

[1] *Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17. pp. 92-93, 1912; Stauffer, C. R., and Schroyer, C. R., The Dunkard series of Ohio: Geol. Survey Ohio Bull. 22, pp. 136-140, 1920; Stout, Wilber, The Monongahela series in eastern Ohio: W. V. Acad. Sci. Proc., Vol. 3, p. 122, 1929.*

Sandstone, massive to shaly, Connellsville	30	0
Coal blossom	--	--
Limestone, nodular	-	8
Shale, sandy, with red beds	38	0
Clay, red, with concretions of hematite	28	0
Shale, sandy	12	0
Limestone, impure and sandy in places, Ames	1	6
Shale, sandy	10	0
Clay shale, red, with nodular limestone, Round Knob	34	0
Coal, thin, Anderson	-	-
Shale, sandy	33	0
Limestone, dark gray, dense fossiliferous, local, Cambridge	1	6
Shale, sandy	20	0
Limestone and fossiliferous shale. In northern part cherty limestone in two parts separated by 18 feet of fossiliferous shale; in southern part two or more beds of rusty gray limestone interlain with sandy shale, Brush Creek member	30	0
Shale, sandy	5	0
Coal, Mason	-	6
Sandstone, shaly to massive	22	0
Coal, thin, Mahoning	-	-
Clay, with ferruginous limestone at top	3	0
Sandstone, massive, Mahoning	33	0
Allegheny series		
Coal and black shale, Upper Freeport or No. 7	-	6
Clay, gray, impure, with occasional nodules of limestone	4	0
Sandstone, grading laterally to shale	37	6
Coal, thin to wanting, Lower Freeport or No. 6a	-	-
Clay, gray, impure, with occasional nodules of limestone	3	0
Sandstone, grading laterally to shale	50	0
Coal, persistent, Middle Kittanning or No 6	-	10

The thickest and most continuous deposits of limestone appearing at the surface in Meigs County occur on the Brush Creek and Cambridge horizons. Quarries have operated in these members at a number of places along the outcrop in Columbia and Salem townships. The chief products have been crushed stone for railroad ballast and for road construction.

The lower part of the Allegheny series and the underlying Pottsville series contain thin limestones on the outcrop in northern Jackson and southern Vinton counties, the most important of which is the Vanport. The presence of the Vanport below drainage in Meigs County is in doubt as limestone near its horizon is not reported in records of wells drilled for oil and gas. Remnants of the Maxville limestone occurring at the top of the Mississippian, still lower in the rock column, are known to be present over small areas in northern Bedford, northwestern Sutton, and central Lebanon townships. Records of wells drilled in Sutton Township show this limestone, ranging in thickness from 15 to 85 feet, at depths below the surface varying from 1,200 to 1,550 feet. In central Lebanon Township the variation in thickness is from 25 to 125 feet and the depth below the surface, from 1,300 to about 1,550 feet.

Lower and Upper Freeport Limestones

The Lower and Upper Freeport limestones, closely associated with the Lower and Upper Freeport coals respectively, have trifling economic importance in this county. Along the outcrops confined to the valley of Storms Creek and its tributaries in western Salem Township and to the valleys of Brushy Fork and Raccoon Creek in western Columbia Township, these members are represented by occasional deposits of nodular limestone, too thin and discontinuous to arouse economic interest.

Mahoning Limestone

The Mahoning limestone, occurring close below the Mahoning coal, is similar to the Freeport limestones in that it is thin, irregular in its occurrence, and is often wanting. It invites little consideration in this county as a source for limestone.

Brush Creek Beds

Outcrops of the Brush Creek member are confined to Columbia and Salem townships in the western part where it is found on an average about 65 feet above the Upper Freeport coal and about 20 feet below the Cambridge limestone. In many localities it is wholly or in part replaced by sandstone. Concerning the character of the member in this county Condit writes as follows: [1]

"The Brush Creek limestones ordinarily consist of two parts, separated by about 20 feet of shale, which is also fossiliferous in some localities, giving a total thickness of as much as 35 feet of marine beds..... In many localities sandy strata occupy the place of one or both of the beds .... The limestones vary greatly in appearance. In the northern part of the county they are cherty beds each about 5 feet thick, but southward they change to impure limestones of a rusty-gray color. Fossils are everywhere plentiful, especially crinoids, giving the rock an appearance somewhat similar to that of the Ames limestone."

The Brush Creek limestone was formerly quarried along Leading Creek about 2 miles south of Albany, where it was crushed and utilized for railroad ballast. It has likewise been quarried near Dexter for road stone. Although rather highly siliceous in composition the limestone has, in general, excellent cementing qualities, a low resistance to wear, superior hardness, and low toughness, — qualities which render the material suitable for a surface macadam stone. [2] For composition of the Brush Creek limestone see analysis of sample from Springfield Township, Gallia County.

[1] *Condit, D. D., op. cit., p. 94, 1912.*

[2] *Morse, W. C., Road Material of Ohio (unpublished manuscript) State Highway Testing Laboratory, Columbus, Vol. II, pp. 571-573, 1935.*

Cambridge Limestone

The field of outcrops of the Cambridge limestone horizon in Meigs County includes much of Salem and Columbia townships, the valley of Leading Creek in southwestern Rutland Township, and the Mud Fork Valley in southwestern Scipio Township. The limestone lacks continuity, however, due to replacement by massive sandstone. Such sandstone bodies occur at scattered localities along Leading Creek and also in the west central part of Columbia Township. Where the limestone is typically developed it is a gray to bluish gray dense-textured fossiliferous stone having a thickness of about 2 feet. It has been utilized in a small way for road stone in Salem Township although for this purpose it is less attractive than the thicker Brush Creek beds occurring some 20 feet lower in the rock section.

The Cambridge limestone has been worked in a small way for road stone in a quarry owned and operated by Meigs County and located on the east side of the road one-fourth mile southeast of the road forks in the northwest quarter of Section 12, Salem Township. The exposures in the quarry are described below:

	Ft.	In.
Shales, chocolate brown to greenish gray, calcareous	8	0
Limestone, gray, dense, fossiliferous, Cambridge	2	0
Bottom of pit.		

The sample of the limestone exposed in this quarry was secured by R. E. Lamborn on September 29, 1942, for chemical analysis.

Sample No. 396

Chemical analysis of Cambridge limestone from County quarry, Section 12, Salem Township, Meigs County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	3.80
Alumina, Al_2O_3	0.95
Ferric oxide, Fe_2O_3	0.40
Ferrous oxide, FeO	0.36
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.75
Calcium oxide, CaO	50.06
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.08
Potassium oxide, K_2O	0.14
Water, hydroscopic, H_2O-	0.08
Water, combined, H_2O+	0.41
Carbon dioxide, CO_2	42.48
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.10
Sulphur trioxide, SO_3	0.13
Manganous oxide, MnO	0.03
Carbon, organic, C	0.17
Hydrogen, organic, H	0.03
Total	99.98

The per cent of each of the compounds probably present in the sample as computed (Lamborn) from the chemical analysis is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	2.16
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.26
Silica, SiO_2	2.68
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.47
Ferrous carbonate, $FeO.CO_2$	0.58
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.01
Calcium phosphate, $3CaO.P_2O_5$	0.22
Calcium sulphate, $CaO.SO_3$	0.22
Calcium carbonate, $CaO.CO_2$	88.97
Magnesium carbonate, $MgO.CO_2$	1.57
Manganese carbonate, $MnO.CO_2$	0.05
Water, hydroscopic, H_2O-	0.08
Organic matter	0.20
Unbalanced components (deficiency, CO_2, H_2O)	+2.51
Total	99.98

Ames Limestone

The Ames limestone is neither thickly developed in Meigs County nor do the exposures possess lithologic features characteristic of the member in areas farther north in Ohio. Over its belt of outcrops which include parts of Salem, Columbia, Rutland, and Scipio townships the member is generally represented by a calcareous layer 1 foot or less in thickness. In places it is a dark nodular fossiliferous limestone, but elsewhere it may be represented by a dark arenaceous impure layer or by a thin bed of dark fossiliferous shale. Locally the Ames member is replaced by sandstone. No economic importance can be attached to the Ames in Meigs County.

Clarksburg Limestone

Condit describes a thin nodular limestone occurring close below the Connellsville sandstone about midway in the interval between the Ames limestone and the Pittsburgh coal which is probably the Clarksburg limestone. [1]

Known deposits of this limestone measure only a few inches in thickness and are local in extent, presenting slight possibilities for utilization.

Pittsburgh Limestone

The horizon of the Pittsburgh limestone reaches the surface over a broad north-south belt extending across Meigs County including parts of Salisbury, Rutland, Bedford, and Scipio townships. Known deposits are confined to small local areas in Bedford and Scipio townships. Here it consists of one or more layers of limestone embedded in or separated by calcareous clays lying close below the Pittsburgh or No. 8 coal. Such a deposit is exposed along a small ravine at an elevation of about 820 feet in the southwest quarter of Section 12, Scipio Township. Here R. E. Wilson has quarried the limestone in a small way and has marketed the pulverized stone for agricultural use. A description of the rock exposures follows:

		Ft.	In.
Shale and surface		1	6
Limestone bluish gray, dense, compact	Pittsburgh	1	10

[1] *Op. cit.*, p. 92.

Shale, brownish gray, calcareous	Pittsburgh (cont.)	....	2	9
Limestone, light bluish to brownish gray, dense, somewhat brittle		....	1	6
Bottom of exposure.				

The 3-feet 4-inches of limestone exposed here was sampled for chemical analysis on September 10, 1942, by R. E. Lamborn.

Sample No. 389

Chemical analysis of Pittsburgh limestone from quarry of R. E. Wilson, Section 12, Scipio Township, Meigs County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	9.65
Alumina, Al_2O_3	2.66
Ferric oxide, Fe_2O_3	0.60
Ferrous oxide, FeO	0.71
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.78
Calcium oxide, CaO	46.58
Strontium oxide, SrO	<0.01
Barium oxide, BaO	0.15
Sodium oxide, Na_2O	0.12
Potassium oxide, K_2O	0.05
Water, hydroscopic, H_2O-	0.38
Water, combined, H_2O+	0.29
Carbon dioxide, CO_2	36.99
Titanium dioxide, TiO_2	0.15
Phosphorus pentoxide, P_2O_5	0.19
Sulphur trioxide, SO_3	0.31
Manganous oxide, MnO	0.02
Carbon, organic, C	0.47
Hydrogen, organic, H	0.05
Total	100.15

The per cent of each of the various mineral compounds probably present in the sample has been computed (Lamborn) from the chemical analysis with results as follows:

Silicates: $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.90
Silicates: $Al_2O_3.2SiO_2.2H_2O$	4.82
Silica, SiO_2	6.52
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.70
Ferrous carbonate, $FeO.CO_2$	1.14
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.15
Calcium phosphate, $3CaO.P_2O_5$	0.41
Calcium sulphate, $CaO.SO_3$	0.40
Barium sulphate, $BaO.SO_3$	0.23
Calcium carbonate, $CaO.CO_2$	82.45
Magnesium carbonate, $MgO.CO_2$	1.63
Manganese carbonate, $MnO.CO_2$	0.03
Water, hydroscopic, H_2O-	0.38

Organic matter	0.52
Unbalanced components (excess CO_2, H_2O)	-1.13
Total	100.15

Redstone Limestone

The known deposits of the Redstone in this county are confined to small local areas in Scipio and Bedford townships where it is represented by nodules or by a few thin layers of limestone interstratified with calcareous shale. Its position in these localities is close below the Redstone (Pomeroy) or No. 8a coal.

Benwood Limestone

The Benwood limestone is not well represented on the outcrop in Meigs County. Its horizon is often marked by red to variegated calcareous shales containing nodules or thin discontinuous layers of impure limestone. The limestone has no economic importance in this county.

MONROE COUNTY

General Considerations

The bedrock geology of Monroe County is similar to that of Belmont County on the north and eastern Washington County on the south in the range of the rock series exposed and in the number and character of the limestone members. The bedrocks which outcrop in this county vary in age from upper Conemaugh of the Pennsylvanian system to strata of the upper Permian. Beds of Conemaugh age are represented by some 150 feet of sandstones, shales, and thin limestones outcropping along the headwaters of Seneca Fork of Wills Creek and its tributaries in Seneca and adjoining townships in the northwest corner of the county. From the outcrop these beds dip to the southeast in the direction of the regional inclination beneath younger and overlying strata. Strata of the Monongahela series reach the surface low on the valley sides along the Ohio River which forms the eastern boundary of the county, along the valley of Sunfish Creek and its major tributaries east of southeastern Malaga Township, and along the valleys of the Little Muskingum River and its chief branches in the southwestern half of the county. The Monongahela is overlain by Permian strata which cap the high hills and ridges in the southwestern third of the county and which is the only series exposed over large areas in the northeastern two-thirds of the area. Strata of Permian age are the surface rocks over an estimated four-fifths of the 457 square miles, which is the total area. The total thickness of the sedimentary series exposed in Monroe County is about 975 feet.

Rock exposures are numerous in Monroe County. Located as it is in the maturely dissected Allegheny Plateau near the headwaters of a preglacial drainage system and far from the southern boundary of continental glaciation, there has been little material introduced to mask the normal topographic features produced by prolonged stream erosion. The valleys are deeply incised, the slopes are steep and rugged, and the divides are narrow and rolling or ridge-like. Near the headwaters the local relief is generally in excess of 200 feet and near the Ohio River it may reach 600 feet. The numerous beds of sandstone and shale penetrated by stream entrenchment aid in producing a bold topography with a minimum of mantle covering except on the rolling divides and uplands. A preliminary generalized section of the bedrocks exposed in Monroe County derived from the work of D. D. Condit, [1] Wilber

[1] *Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17, p. 164, 1912.*

Stout, [1] and C. R. Stauffer and C. R. Schroyer [2] is given below.

Generalized Section of Bedrocks Outcropping in Monroe County

	Ft.	In.
Permian system		
Shale and sandstone, with an occasional thin local deposit of nodular limestone in lower part, and one or more thin coal beds. Members not differentiated	435	0
Coal and carbonaceous shale, persistent, Washington	3	5
Shale, gray to red, with local deposits of sandstone, Washington sandstone horizon	42	3
Coal and black shale; locally developed, Waynesburg B	-	7
Shale, red and gray, with local deposits of sandstone, Mannington sandstone horizon	26	0
Coal and black shale; locally developed, Waynesburg A	2	7
Limestone, dark, bedded to nodular, in clay shale, locally developed, Mount Morris	3	0
Shale, generally gray, arenaceous	11	4
Sandstone, locally wanting, Waynesburg	22	0
Shale, gray, siliceous	2	0
Limestone, dark blue, unsteady, Elm Grove	1	9
Shale, gray, argillaceous, Cassville shale horizon	1	2
Pennsylvanian system		
Monongahela series		
Coal, variable, generally shaly, Waynesburg or No. 11	-	9
Shale and sandstone, Gilboy sandstone horizon	23	3
Coal, locally present, Little Waynesburg	-	3
Limestone, with marly shale interstratified, Waynesburg	8	0
Shale and sandstone, Uniontown sandstone horizon	24	0
Coal, variable; locally with fair development, Uniontown or No. 10	2	5
Limestone with shale partings, Uniontown	6	5
Sandstone, locally developed, Arnoldsburg	38	0
Shale, light olive green; seldom present, Fulton	2	4
Limestone, gray, generally dense with some calcareous shale, Benwood	37	0
Sandstone, local, Upper Sewickley	12	0
Shale, calcareous	2	6

[1] *Unpublished notes on the Monongahela series by Wilber Stout.*

[2] *Stauffer, C. R. and Schroyer, C. R., The Dunkard series of Ohio: Geol. Survey Ohio Bull. 22, pp. 78-112, 1920*

Coal, variable, locally present, Meigs Creek or No. 9	1	4
Shale and sandstone, Lower Sewickley sandstone horizon	30	0
Coal, shaly, irregular, Fishpot	1	10
Limestone, gray, generally dense, with some marly shale, Fishpot	41	0
Coal, generally wanting, Redstone, or No. 8a	-	-
Limestone, gray to dark, generally dense, with some marly shale, Redstone	16	3
Sandstone, local and shale, Pittsburgh sandstone horizon	12	0
Coal, irregular in thickness, Pittsburgh or No. 8	2	5
Conemaugh series		
Clay	1	6
Limestone, dark gray; in two layers separated by clay shale, Pittsburgh	6	0
Shale	9	0
Limestone	3	0
Shale, sandy, with layers of sandstone, Bellaire sandstone horizon	30	0
Limestone, in layers interlain with clay. Some are buff colored and have embedded lumps of white limestone, Summerfield	5	0
Clay shale, with layers of sandstone and red clay	79	0
Shale, sandy, with irregular layers of calcareous concretions and several layers of reddish brown, impure fossiliferous limestone	25	0

Of the ten limestone members which have been recognized in the rock series outcropping in Monroe County, as detailed above, those of the upper Conemaugh and lower Permian are either so limited in areal distribution or are so thin and discontinuous on the outcrop that they contribute little to the limestone resources. The limestone beds of the Monongahela are of chief importance. These have been utilized from time to time from several localities. Loose limestone blocks occurring as float along stream beds have been hauled to some central location and there pulverized for agricultural use or crushed for road stone or for other uses. Small quarries located chiefly in valleys in Malaga, Seneca, Sunbury, Center, Franklin, Washington, and Bethel townships have operated at various times. The life of such individual operations is generally short, as the rugged topography and predominating steep slopes generally prevent the removal of large quantities of stone before the overburden becomes too thick for quarrying at low cost. The members which have been utilized chiefly are the Redstone, Fishpot, and the Benwood-Uniontown series.

The thin limestones occurring in outcrops of the Pottsville and Allegheny series in Ohio are expected below drainage in Monroe County. Little is known concerning their actual occurrence, however, as they are rarely reported in the records of deep wells which have been drilled for oil and gas in this county. Immediately below the Pottsville series the Maxville limestone of Mississippian age has been encountered over large areas in the central and west central parts. Where this limestone is wanting, it was eroded away before the deposition of the sediments forming the coal measure series. Where present the limestone varies in thickness from 5 feet to 127 feet and its depth below the surface ranges from 1,000 to 1,800 feet. A summary of its distribution, thickness, and depth below the surface, as gleaned from a study of well records, is presented in the following table. [1]

Thickness and Depth of the Maxville Limestone

Township	Variations in depth to limestone Feet	Variations in thickness of limestone Feet	Average thickness Feet
Bethel	1,051 to 1,400	19 to 126	90
Washington	1,100 to 1,400	35 to 120	95
Benton (S)	1,400 to 1,600	32 to 127	69
Benton (N)	1,400 to 1,750	60 to 70	65
Perry (S)	1,375 to 1,650	60 to 80	65
Perry (N. W.)	1,100 to 1,500	70 to 119	95
Franklin	1,000 to 1,300	7 to 49	30
Wayne	1,000 to 1,450	50 to 90	36
Summit	1,200 to 1,500	6 to 110	50
Center	1,160 to 1,650	11 to 122	53
Green	1,300 to 1,700	43 to 124	83
Adams	1,200 to 1,700	50 to 125	70
Ohio (S. E.)	1,400 to 1,800	46 to 90	59
Ohio (N. E.)	1,350 to 1,900	70 to 95	80
Salem (S. E.)	1,300 to 1,800	53 to 80	65
Salem (S. W.)	1,675 to 1,850	35 to 58	48
Salem (N. E.)	1,200 to 1,800	20 to 60	38
Sunbury	1,200 to 1,625	10 to 83	51
Malaga	1,200 to 1,490	5 to 90	56

Below the horizon of the Maxville limestone in Monroe County shale with a few thin sandstones extend to an almost undetermined depth. Only one well in Monroe County has penetrated these beds. This well, drilled on the Louisa Kerr farm, Section 6, Center Township, near Woodsfield, passed through the Maxville limestone at a depth of 1,516 feet and reached the Middle Devonian limestones at a depth of about 5,330 feet.

Summerfield Limestone

Outcrops of the Summerfield limestone in Monroe County are confined to the valley of Seneca Fork of Wills Creek and its tributaries in northern and western Seneca Township. Here the member consists of several layers of gray limestone interlain with thin calcareous clay shale, the series having a thickness of 5 or 6 feet. For analyses of the Summerfield limestone see sections of this report dealing with that member in Noble and Guernsey counties.

Redstone Limestone

The outcrops of the Redstone limestone horizon in this county are confined chiefly to a few deep valleys in Seneca, Franklin, and Bethel townships along its western edge. In these valleys the limestone is poorly represented for its place in the section is generally occupied with sandstone and shale.

[1] *Lamborn, R. E., Recent information on the Maxville limestone: Geol. Survey Ohio Inf. Circ. No. 3, pp. 12-13, 1945.*

Along Cranenest Fork in eastern Wayne Township a limestone crops out close above water level which was formerly quarried by stripping along the valley bottom on the Lloyd King property in Section 1. It is overlain by a thin coal bed which according to identifications and measurements by A. T. Cross in 1946 occurs about 51 feet below the Meigs Creek coal. It probably represents the Redstone coal. Both the coal and underlying limestone crop out on the west side of the highway just north of the road forks in the north central part of Section 1, where the succession is as follows:

		Ft.	In.
Sandrock. Estimated thickness		8	0
Shale, gray black, sandy		4	0
Clay shale, bluish gray, soft		3	0
Coal blossom, Redstone or 8a		-	6
Clay shale, bluish gray, soft		-	10
Limestone, dark bluish gray, dense, compact, sampled	Redstone	1	10
Limestone, dark bluish gray, dense, compact, sampled	Redstone	1	8
Shale, calcareous, not sampled	Redstone	-	2
Limestone, dark bluish gray, sampled	Redstone	-	7
Limestone, dark bluish gray, sampled	Redstone	-	11
Clay shale, bluish gray, not sampled	Redstone	-	2 1/2
Limestone bed, bluish gray, hard, sampled	Redstone	1	6
Bottom of exposure.			

The 6 feet 6 inches of limestone exposed at this locality was sampled by R. E. Lamborn on June 26, 1942, for chemical analysis.

Sample No. 387

Chemical analysis of Redstone limestone from outcrop along highway, north central Section 1, Wayne Township, Monroe County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	9.61
Alumina, Al_2O_3	1.74
Ferric oxide, Fe_2O_3	0.60
Ferrous oxide, FeO	0.76
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	1.43
Calcium oxide, CaO	45.48
Strontium oxide, SrO	<0.01
Barium oxide, BaO	0.15
Sodium oxide, Na_2O	0.18
Potassium oxide, K_2O	0.23
Water, hydroscopic, H_2O-	0.42

Water, combined, H_2O+	0.57
Carbon dioxide, CO_2	37.24
Titanium dioxide, TiO_2	0.15
Phosphorus pentoxide, P_2O_5	0.05
Sulphur trioxide, SO_3	0.07
Manganous oxide, MnO	0.01
Carbon, organic, C	1.21
Hydrogen, organic, H	0.17
Total	100.07

The per cent of each of the mineral constituents probably present in Sample No. 387 as calculated (Lamborn) from the chemical analysis is given below.

Silicates	$(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	4.16
	$Al_2O_3.2SiO_2.2H_2O$	0.27
Silica, SiO_2		7.56
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$		0.70
Ferrous carbonate, $FeO.CO_2$		1.22
Iron disulphide, FeS_2		<0.01
Titanium dioxide, TiO_2		0.15
Calcium phosphate, $3CaO.P_2O_5$		0.11
Barium sulphate, $BaO.SO_3$		0.21
Calcium carbonate, $CaO.CO_2$		80.97
Magnesium carbonate, $MgO.CO_2$		2.99
Manganese carbonate, $MnO.CO_2$		0.02
Water, hydroscopic, H_2O-		0.42
Organic matter		1.38
Unbalanced components (excess CO_2, H_2O)		-0.09
Total		100.07

Fishpot Limestone

The horizon of the Fishpot limestone is generally marked on the outcrop in Monroe County by several beds of gray to dark gray, dense limestone which is somewhat argillaceous and siliceous, interstratified with calcareous shale. The thickness of this limestone and shale series may range from a few feet to 40 feet or more but the proportion of limestone to shale is generally greater in the upper part. The top of the series occurs close below the Fishpot coal or about 30 feet on an average below the well known Meigs Creek or No. 9 coal. Outcrops of the Fishpot limestone member are confined chiefly to the valley of Seneca Fork of Wills Creek and its tributaries in Seneca Township, western Summit Township, and western Malaga Township; to Clear Fork of the Little Muskingum River and its tributaries in Franklin and northern Bethel townships; and to Cranenest Fork of the Little Muskingum River in eastern Wayne Township. The stone has been quarried at a number of localities in Seneca Township at various times and to a less extent in western Malaga, western Summit, and eastern Wayne townships.

In 1941 the Fishpot limestone was being quarried for agricultural use by Kohrig and Ankron of Woodsfield, Ohio, along a small tributary to Paynes Fork in the west central part of the northeast quarter of Section 28, Malaga Township. A description of the exposures at this locality is as follows:

		Ft.	In.
Shale		8	0
Coal, weathered	Fishpot	-	10
Clay shale parting	Fishpot	-	4
Coal, shaly, weathered	Fishpot	-	6

			Feet	Inches
Clay shale, dark, calcareous			-	8
Limestone, bluish gray, dense, flint-like fracture, lower part laminated, sampled	Fishpot		2	10
Shale, bluish gray, not sampled			-	5
Limestone, bluish gray, dense, brittle, sampled			1	6
Limestone, bluish gray, dense, brittle, sampled			1	0
Shale, bluish gray, calcareous, not sampled			-	2
Limestone, light bluish gray, dense, brittle, sampled			3	0
Shale, bluish gray, calcareous, not sampled			-	4
Limestone, light bluish gray, dense, sampled			2	10
Bottom of excavation.				

The 11 feet 2 inches of limestone described in the section was sampled for chemical analysis by R. E. Lamborn on August 13, 1941.

Sample No. 371

Chemical analysis of Fishpot limestone from quarry of Kohrig and Ankron, Section 28, Malaga Township, Monroe County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	10.72
Alumina, Al_2O_3	2.15
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	0.88
Iron disulphide, FeS_2	0.12
Magnesium oxide, MgO	5.70
Calcium oxide, CaO	40.04
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.05
Potassium oxide, K_2O	0.30
Water, hydroscopic, H_2O-	0.68
Water, combined, H_2O+	0.66
Carbon dioxide, CO_2	38.16
Titanium dioxide, TiO_2	0.14
Phosphorus pentoxide, P_2O_5	0.11
Sulphur trioxide, SO_3	0.03
Manganous oxide, MnO	0.20
Carbon, organic, C	0.08
Hydrogen, organic, H	--
Total	100.05

The per cent of the various mineral constituents probably present in Sample No. 371 as calculated (Lamborn) from the chemical analysis is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	3.15
Silicates $Al_2O_3.2SiO_2.2H_2O$	2.35
Silica, SiO_2	8.19
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	1.42
Iron disulphide, FeS_2	0.12
Titanium dioxide, TiO_2	0.14
Calcium phosphate, $3CaO.P_2O_5$	0.24
Calcium sulphate, $CaO.SO_3$	0.05
Calcium carbonate, $CaO.CO_2$	71.19
Magnesium carbonate, $MgO.CO_2$	11.91
Manganese carbonate, $MnO.CO_2$	0.32
Water, hydroscopic, H_2O	0.68
Organic matter	0.08
Unbalanced components (deficiency CO_3, H_2O)	+0.17
Total	100.05

Limestone probably Fishpot in age has been quarried in Section 3, Wayne Township, by Clem Smithenberger, of Woodsfield, Ohio, and marketed chiefly for road stone. The quarry is located in the southeastern corner of the section on property of Lloyd King. A description of the exposures in the quarry is as follows:

		Ft.	In.
Limestone, greenish gray, shaly, not sampled	Fishpot	1	10
Limestone, greenish gray, shaly, not sampled	Fishpot	3	9
Limestone, bluish to brownish gray, hard, tough, sampled	Fishpot	3	0
Limestone, bluish gray, dense, argillaceous, brittle, sampled	Fishpot	2	8
Limestone, greenish gray, shaly, with a few streaks of brown shaly limestone, not sampled	Fishpot	3	0
Limestone, greenish gray, shaly, not sampled	Fishpot	1	8
Limestone, light gray, dense, brittle, heavy-bedded, not sampled	Fishpot	2	0
Bottom of quarry.			

The heavy-bedded limestone forming the middle part of the exposure and having a thickness of 5 feet 8 inches as indicated in the section above was sampled by R. E. Lamborn on June 26, 1942, for chemical analysis.

Sample No. 388

Chemical analysis of Fishpot (?) limestone from quarry of Clem Smithenberger, Section 3, Wayne Township, Monroe County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	17.38
Alumina, Al_2O_3	5.30
Ferric oxide, Fe_2O_3	1.42
Ferrous oxide, FeO	1.18
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	8.83
Calcium oxide, CaO	28.80
Strontium oxide, SrO	<0.01
Barium oxide, BaO	0.18
Sodium oxide, Na_2O	0.24
Potassium oxide, K_2O	0.42
Water, hydroscopic, H_2O-	0.59
Water, combined, H_2O+	1 45
Carbon dioxide, CO_2	33.22
Titanium dioxide, TiO_2	0.23
Phosphorus pentoxide, P_2O_5	0.08
Sulphur trioxide, SO_3	0.03
Manganous oxide, MnO	0.04
Carbon, organic, C	0.54
Hydrogen, organic, H	0.08
Total	100.01

The per cent of each of the mineral constituents probably present in Sample No. 388 as determined by calculation (Lamborn) from the chemical analysis is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	8.01
Silicates $Al_2O_3.2SiO_2.2H_2O$	3.17
Silica, SiO_2	12.90
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	1.66
Ferrous carbonate, $FeO.CO_2$	1.90
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.23
Calcium phosphate, $3CaO.P_2O_5$	0.17
Barium sulphate, $BaO.SO_3$	0.09
Calcium carbonate, $CaO.CO_2$	51.24
Magnesium carbonate, $MgO.CO_2$	18.45
Manganese carbonate, $MnO.CO_2$	0.06
Barium carbonate, $BaO.CO_2$	0.16
Water, hydroscopic, H_2O-	0.59
Organic matter	0.62
Unbalanced components (deficiency CO_2, H_2O)	+0.76
Total	100.01

Benwood - Arnoldsburg - Uniontown Limestone Series

The Benwood-Arnoldsburg - Uniontown limestone series includes the somewhat argillaceous limestones with interbedded calcareous shales occurring in the odd 100 - foot interval between the Meigs Creek or No. 9 coal and the Uniontown or No. 10 coal. Where the complete stratigraphic column is represented in outcrops, the succession of members in ascending order is as follows: Meigs Creek coal, Upper Sewickley sandstone, Benwood limestone, Fulton green shale, Arnoldsburg limestone, Arnoldsburg coal, Arnoldsburg sandstone, Uniontown limestone, and Uniontown coal. Owing to the absence of the Arnoldsburg coal, to the local development of the Fulton shale and Arnoldsburg sandstone, and to the similarity in lithologic characteristics of the three limestone members, it is not possible to separate the Benwood, Arnoldsburg, and Uniontown limestones in all outcrops in Monroe County. In places the entire series between the coals is made up of calcareous shale with layers of limestone interstratified. The limestone layers are generally more prevalent however and the shale partings a less fraction of the whole in the lower part of the series corresponding in position with the Benwood and Arnoldsburg members. Outcrops of the horizon of the Benwood - Arnoldsburg - Uniontown limestone series are widely distributed in Monroe County. They are present along the valley of Sunfish Creek in Salem, Adams, Center, southern Sunbury, and southeastern Malaga townships; along the valley of Seneca Fork of Wills Creek and its tributaries in Seneca Township and in western Malaga and western Summit townships; along Clear Fork in Franklin Township; in the valleys of Clear Fork and Straight Creek in Washington Township; along the valley of the Little Muskingum River and its tributaries in Perry Township; and along Prond Fork, Brister Fork, and Cranenest Fork in Wayne Township. Limestone from this series is known to have been quarried at a few places in Center, Franklin, and Washington townships.

Limestone probably Benwood in age has been worked on a small scale for agricultural purposes along Standingstone Creek in Center Township. When this region was visited by the writer in 1943, H. F. Zerger of Woodsfield, Ohio, was quarrying limestone near the creek level in the extreme northeast corner of Section 18. After crushing and screening the coarser material was pulverized for agricultural limestone, the finer screenings being utilized for roads. A description of the exposures at the place of quarrying is as follows:

		Ft.	In.
Limestone, mottled light bluish to brownish gray, dense, brittle, sampled	Benwood	3	3
Limestone, gray to light brownish gray, dense to finely crystalline, sampled		1	0
Shale, calcareous		-	2 1/2
Limestone, bluish gray, dense to finely crystalline, in part nodular, sampled		2	0
Bottom of quarry.			

The limestones described above were sampled for chemical analysis by R. E. Lamborn on September 29, 1943. Sample No. 426 includes the 4 feet 3 inches of limestone above the shale parting whereas Sample No. 427 is of the lower 2 feet exposed.

<u>Samples Nos. 426, 427</u>

Chemical analyses of Benwood limestone from quarry of H. F. Zerger, Section 18, Center Township, Monroe County, E. Chadbourn, analyst

	Sample No. 426 Per cent	Sample No. 427 Per cent
Silica, SiO_2	14.33	8.88
Alumina, Al_2O_3	2.92	2.47
Ferric oxide, Fe_2O_3	0.36	0.24
Ferrous oxide, FeO	1.52	0.54
Iron disulphide, FeS_2	0.07	0.06
Magnesium oxide, MgO	14.49	1.44
Calcium oxide, CaO	26.83	46.69
Sodium oxide, Na_2O	0.15	0.09
Potassium oxide, K_2O	0.75	0.54
Water, hydroscopic, H_2O-	0.25	0.23
Water, combined, H_2O+	1.20	0.80
Carbon dioxide, CO_2	36.60	37.32
Titanium dioxide, TiO_2	0.11	0.10
Phosphorus pentoxide, P_2O_5	0.07	0.08
Sulphur trioxide, SO_3	0.04	0.02
Manganous oxide, MnO	0.11	0.08
Total	99.80	99.58

The per cent of each of the various mineral constituents in Sample No. 426 as calculated (Lamborn) from the chemical analysis is as follows:

Silica and hydrated aluminum silicates of sodium and potassium	19.29
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.42
Ferrous carbonate, $FeO.CO_2$	2.45
Iron disulphide, FeS_2	0.07
Titanium dioxide, TiO_2	0.11
Calcium phosphate, $3CaO.P_2O_5$	0.15
Calcium sulphate, $CaO.SO_3$	0.07
Calcium carbonate, $CaO.CO_2$	47.69
Magnesium carbonate, $MgO.CO_2$	30.28
Manganese carbonate, $MnO.CO_2$	0.18
Water, hydroscopic, H_2O-	0.25
Unbalanced components, (excess CO_2)	-1.16
Total	99.80

The per cent of each of the various mineral constituents in Sample No. 427 as calculated (Lamborn) from the chemical analysis is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	5.80
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.39
Silica, SiO_2	6.11
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.28
Ferrous carbonate, $FeO.CO_2$	0.87
Iron disulphide, FeS_2	0.06
Titanium dioxide, TiO_2	0.10
Calcium phosphate, $3CaO.P_2O_5$	0.17
Calcium sulphate, $CaO.SO_3$	0.03
Calcium carbonate, $CaO.CO_2$	83.12
Magnesium carbonate, $MgO.CO_2$	3.01
Manganese carbonate, $MnO.CO_2$	0.13
Water, hydroscopic, H_2O-	0.23
Unbalanced components (excess CO_2, H_2O)	-0.72
Total	99.58

Limestone belonging to the lower part of the Benwood-Uniontown series outcrops at a number of places along Sunfish Creek in Salem and Adams townships. The exposures described below are located along the south bank of the stream in the south central part of Section 7, Salem Township, about three-eighths of a mile northeast of Cameron.

		Ft.	In.
Shale, dark bluish to greenish gray, calcareous	Arnoldsburg ?	10	4
Limestone, dark bluish gray, hard, tough, sampled		1	4
Shale, calcareous, not sampled		1	0
Limestone, dark bluish gray, hard, sampled		1	0
Shale, bluish gray, calcareous, not sampled		1	4
Limestone, dark bluish gray to brown, tough to brittle, sampled		3	0
Shale, bluish gray, calcareous, not sampled		-	6
Limestone, gray to light bluish gray, somewhat brittle, sampled		3	0
Shale, light to dark olive green,	Fulton ?	2	4
Limestone, light gray to white, dense, rather brittle, sampled	Benwood	3	0
Limestone, gray, shaly, sampled		1	6
Covered interval		-	6
Water level, Sunfish Creek.			

Two samples of limestone were secured at this locality for chemical analysis by R. E. Lamborn on September 29, 1943. Sample No. 428 includes the 4 feet 6 inches of limestone (Benwood ?) below the green shale (Fulton ?) whereas Sample No. 429 is from the 8 feet 4 inches of limestone (Arnoldsburg ?) above the green shale.

<u>Samples No. 428, 429</u>

Chemical analyses of Benwood (?) and Arnoldsburg (?) limestones exposed along Sunfish Creek, Section 7, Salem Township, Monroe County, E. Chadbourn, analyst

	Sample No. 428 Per cent	Sample No. 429 Per cent
Silica, SiO_2	15.75	18.73
Alumina, Al_2O_3	2.23	3.94
Ferric oxide, Fe_2O_3	0.22	0.70
Ferrous oxide, FeO	1.53	1.56
Iron disulphide, FeS_2	0.07	0.06
Magnesium oxide, MgO	14.65	7.49
Calcium oxide, CaO	26.58	32.05
Sodium oxide, Na_2O	0.14	0.15
Potassium oxide, K_2O	0.47	0.76
Water, hydroscopic, H_2O-	0.33	0.43
Water, combined, H_2O+	0.97	1.53
Carbon dioxide, CO_2	36.74	32.12
Titanium dioxide, TiO_2	0.09	0.20
Phosphorus pentoxide, P_2O_5	0.05	0.05
Sulphur trioxide, SO_3	0.03	0.03
Manganous oxide, MnO	0.10	0.10
Total	99.95	99.90

The per cent of each of the various compounds present in Sample No. 428 as calculated (Lamborn) from the chemical analysis is as follows:

Silicates $(Na, K)_2O . 3Al_2O_3 . 6SiO_2 . 2H_2O$	5.70
Silicates $Al_2O_3 . 2SiO_2 . 2H_2O$	0.03
Silica, SiO_2	13.12
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.26
Ferrous carbonate, $FeO. CO_2$	2.46
Iron disulphide, FeS_2	0.07
Titanium dioxide, TiO_2	0.09
Calcium phosphate, $3CaO. P_2O_5$	0.11
Calcium sulphate, $CaO. SO_3$	0.05
Calcium carbonate, $CaO. CO_2$	47.30
Magnesium carbonate, $MgO. CO_2$	30.62
Manganese carbonate, $MnO. CO_2$	0.16
Water, hydroscopic, H_2O-	0.33
Unbalanced components (excess CO_2, H_2O)	-0.35
Total	99.95

The per cent of each of the various compounds present in Sample No. 429 as calculated (Lamborn) from the chemical analysis follows:

Silicates $(Na, K)_2O . 3Al_2O_3 . 6SiO_2 . 2H_2O$	8.28
Silicates $Al_2O_3 . 2SiO_2 . 2H_2O$	1.84
Silica, SiO_2	14.10
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.82
Ferrous carbonate, $FeO. CO_2$	2.51
Iron disulphide, FeS_2	0.06
Titanium dioxide, TiO_2	0.20
Calcium phosphate, $3CaO. P_2O_5$	0.11
Calcium sulphate, $CaO. SO_3$	0.05
Calcium carbonate, $CaO. CO_2$	57.06
Magnesium carbonate, $MgO. CO_2$	15.65
Manganese carbonate, $MnO. CO_2$	0.16
Water, hydroscopic, H_2O-	0.43
Unbalanced components (excess CO_2, H_2O)	-1.37
Total	99.90

In 1942 Turner and Hill of Graysville were quarrying limestone on the Frank Rose property in Section 19, Washington Township, and pulverizing it for agricultural use. The quarry is located along a small valley tributary to Witten Run from the north in the west central part of the section, about one-fourth of a mile from the highway. The character and thickness of the beds exposed are described as follows:

		Ft.	In.
Shale, mottled reddish brown to bluish gray, calcareous		8	0
Limestone, light and dark bluish gray, dense, compact, in part brecciated, sampled	Benwood	-	10
Limestone, light bluish gray, dense, compact, sampled	Benwood	1	8
Limestone, light bluish gray, hard, with fracture of flint, sampled	Benwood	-	8
Shale, bluish to greenish gray and red brown		1	0
Hematite, concretionary layer		-	2
Clay shale, greenish gray		1	2
Creek level.			

The Benwood limestone exposed here, having a total thickness of 3 feet, was sampled for chemical analysis by R. E. Lamborn on June 25, 1942.

Sample No. 386

Chemical analysis of Benwood limestone from quarry of Turner and Hill on the Frank Rose property, Section 19, Washington Township, Monroe County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	4.51
Alumina, Al_2O_3	1.42
Ferric oxide, Fe_2O_3	0.29
Ferrous oxide, FeO	0.54
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	1.96
Calcium oxide, CaO	49.24
Strontium oxide, SrO	<0.01
Barium oxide, BaO	0.11
Sodium oxide, Na_2O	0.21
Potassium oxide, K_2O	0.15
Water, hydroscopic, H_2O-	0.08
Water, combined, H_2O+	0.38
Carbon dioxide, CO_2	40.91
Titanium dioxide, TiO_2	0.08
Phosphorus pentoxide, P_2O_5	0.01
Sulphur trioxide, SO_3	none

Manganous oxide, MnO	0.01
Carbon, organic, C	0.39
Hydrogen, organic, H	0.04
Total	100.33

The per cent of each of the various constituents in Sample No. 386 as determined by calculation (Lamborn) from the chemical analysis is as follows:

Silica and hydrated aluminum silicates of sodium and potassium	6.62
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.34
Ferrous carbonate, $FeO. CO_2$	0.87
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.08
Calcium phosphate, $3CaO. P_2O_5$	0.02
Calcium carbonate, $CaO. CO_2$	87.86
Magnesium carbonate, $MgO. CO_2$	4.10
Manganese carbonate, $MnO. CO_2$	0.01
Barium carbonate, $BaO. CO_2$	0.14
Water, hydroscopic, H_2O-	0.08
Organic matter	0.43
Unbalanced components (excess CO_2)	-0.22
Total	100.33

Waynesburg Limestone

The Waynesburg limestone which occurs close below the Little Waynesburg coal is only locally represented in outcrops in Monroe County. Over much of this county sandstone and sandy shales occupy the entire interval between the Uniontown coal below and the Little Waynesburg coal above, thus replacing the Waynesburg limestone. In parts of Switzerland, Sunbury, Adams, and Center townships, however, the Little Waynesburg coal is closely underlain by one or more beds of dark compact limestone interbedded with calcareous shale representing the Waynesburg limestone member. In places this limestone and shale series extends downward nearly to the Uniontown coal. The Waynesburg limestone has not been utilized to any extent in Monroe County.

Elm Grove Limestone

The Elm Grove limestone is generally present where due on the outcrop in Monroe County except in those localities where the Waynesburg sandstone has transgressed its horizon. As generally developed the Elm Grove is made up of one or more beds of dark bluish gray to black, hard, dense limestone embedded in clay shale. The thickness of the limestone ranges from a few inches to 5 feet or more. The position of the member is generally from 1 to 10 feet above the Waynesburg coal from which it is usually separated by dark shale. Although outcrops of the Elm Grove horizon are due in parts of every township and the limestone is known to be present over extensive areas, little economic use has been made of it in this county.

Mount Morris Limestone

The Mount Morris limestone, which in stratigraphic succession belongs close below the Waynesburg A coal and generally from 30 to 40 feet above the Waynesburg coal, has been recognized at a few localities in Monroe County where it consists of nodules or a few thin layers of light limestone embedded in or interstratified with calcareous shale. The economic importance of this horizon in Monroe County is trifling.

MORGAN COUNTY

General Considerations

Morgan County, embracing an area of about 420 square miles, contains within its borders outcrops of beds which have a total average thickness of approximately 700 feet. The series represented by these outcrops includes the upper 100 feet of the Allegheny, the Conemaugh, and the Monongahela of the Pennsylvanian system and approximately 150 feet of the lower part of the Washington series of the Permian system. As the general structural condition in the county is that of a gentle slope to the southeast toward the axis of the Parkersburg-Lorain syncline, which passes through Center and Manchester townships in the eastern part, the oldest beds, the Allegheny, are found close above drainage in the northwest corner, whereas the youngest, the Permian, cap the hills along the axis of the syncline. Rock outcrops are numerous in the county as glacial drift deposits are wanting and as the region has been maturely dissected by stream erosion. A general section of the beds exposed with the names of the members recognized is given below. [1]

General Section of Bedrocks Outcropping in Morgan County

	Ft.	In.
Permian system		
Washington series		
Sandstone and shale with one or more probable thin coal beds; to hilltops	100	0
Coal, thin, local Waynesburg A	-	1
Sandstone and shale, Waynesburg sandstone horizon	44	0
Limestone, dark blue, hard, local, Elm Grove	-	4
Shale, gray	-	8
Pennsylvanian system		
Monongahela series		
Coal and bone shale, Waynesburg or No. 11	-	7
Shale, argillaceous, drab	1	0
Shale, gray, arenaceous, with thin lenses of sandstone, Gilboy sandstone horizon	13	4
Coal and bone shale, Little Waynesburg	-	4
Shale, drab, calcareous, grainy	9	0
Shale, calcareous, pink, with occasional layers of limestone	12	0
Shale, gray, arenaceous, with local lenses of sandstone, Uniontown sandstone horizon	23	7
Coal and bone shale, Uniontown or No. 10	-	9
Shale, gray, arenaceous irregular, local	2	6
Limestone, interstratified with calcareous shale, Uniontown	31	3

[1] *Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17, pp. 133-134, 1912: Stout, Wilber, the Monongahela series in eastern Ohio: W. Va. Acad. Sci. Proc., Vol. 3, pp. 121-122, 1929.*

Sandstone and arenaceous gray shale, very local, 1 to 15 feet in thickness, Fulton horizon	3	0
Limestone, interstratified with calcareous shale, Benwood	63	0
Coal and partings, Meigs Creek or No. 9	2	2
Clay shale, gray to drab	3	0
Shale and shaly sandstone	11	10
Coal and bone shale, Fishpot	-	2
Fishpot: Limestone, massive, with shale partings	10	5
Fishpot: Shale, calcareous, with some limestone layers	19	3
Shale, gray, arenaceous	3	3
Coal and bone shale, Redstone or No. 8a	-	4
Shale, gray, arenaceous, with local lenses of sandstone, Pittsburgh sandstone horizon	22	10
Coal and bone shale, Pittsburgh or No. 8	-	11
Conemaugh series		
Clay with a number of beds of limestone, Pittsburgh limestone	13	0
Shale, sandy, with sandstone in some localities, Bellaire sandstone horizon	35	0
Limestone, interstratified with calcareous clay, Summerfield	4	0
Clay shale, generally red, with nodules of limestone and hematite	45	0
Sandstone, shaly	30	0
Shale, sandy, with one or more layers of impure, fossiliferous limestone, Skelley horizon	16	0
Shale, sandy, with local deposits of sandstone	21	0
Limestone, gray, fossiliferous, Ames	1	6
Shale, sandy	11	0
Coal, Harlem	1	0
Shale, sandy, and shaly sandstone	24	0
Limestone, fossiliferous, somewhat local, Ewing	3	0
Sandstone, massive, shale in western part of county, Cow Run	25	0
Shale, carbonaceous, fossiliferous, Portersville horizon	4	0
Coal, local, Anderson	1	8
Clay shale, with calcareous concretions	10	0
Clay, with nodules of fossiliferous limestone, Cambridge limestone horizon	4	0
Shale, sandy	28	0
Brush Creek: Limestone, sandy, fossiliferous, in layers and nodules	6	0
Brush Creek: Shale, sandy	18	0
Brush Creek: Limestone, sandy, fossiliferous, in layers	5	0

Coal, thin, Mason		-	-
Sandstone, shaly		19	0
Coal, wanting, Mahoning		-	-
Clay with some limestone, Mahoning		3	0
Sandstone, shaly, Mahoning		37	0
Allegheny series			
Coal, persistent, Upper Freeport		-	10
Clay, arenaceous		5	0
Shale and sandstone, Upper Freeport sandstone horizon		38	0
Coal, Lower Freeport		-	10
Clay, calcareous		5	0
Shale and sandstone, Lower Freeport sandstone horizon		40	0
Coal, bony	Middle Kittanning or No. 6	-	5
Coal, good	Middle Kittanning or No. 6	1	6
Parting	Middle Kittanning or No. 6	-	1
Coal, good	Middle Kittanning or No. 6	2	0

The limestones which have been recognized on the outcrop in Morgan County are confined chiefly to the Conemaugh and Monongahela series. The limestones of the Conemaugh, although numerous, are generally thin and are often nodular and discontinuous, the thickest members being places very impure. In striking contrast the limestones of the Monongahela occur in heavier development, are more persistent in character, and consequently have received the most attention as sources of material for local use. Quarries have operated in these limestones in Union, Bristol, Meigsville, and Windsor townships.

At least 300 feet of Pennsylvanian strata occurs below drainage in northwestern Morgan County. This thickness includes the Pottsville series and the lower 100 feet of the Allegheny series, both of which contain thin limestone members on the outcrop in counties adjacent on the west. The Pottsville is underlain in central and eastern York Township and in central and southwestern Deerfield Township by Maxville limestone ranging in thickness, according to well records, from 30 to 70 feet. Here the limestone is reached in wells at depths from the surface varying from 400 to 750 feet. The Maxville is also penetrated in borings for oil and gas in the northwest corner of Penn Township. Underlying the Maxville limestone, shales with one or more thin sandstones comprise the rock series extending to depths below sea level ranging from 1, 500 feet in northwestern York Township to approximately 3, 100 feet in the southeastern part of Center Township.

Mahoning Limestone

Outcrops of the Mahoning horizon are confined to the valley of Black Fork and its tributaries in the western part of York Township. The limestone is of the fresh or brackish water type consisting of nodular masses of stone embedded in calcareous clays and shales and has no economic values in this county.

Brush Creek Limestone

The Brush Creek limestone occurs above drainage along the valley of East Branch of Sunday Creek in western Union and Deerfield townships, along the valley of Black Fork of Moxahala Creek in western York Township, and along the Muskingum Valley in eastern York Township, eastern Deerfield Township, and western Bloom Township. It consists for the most part of cherty, sandy, impure limestone which varies in thickness from a few inches to 6 feet or more. Locally deposits of black shale with nodular limestone embedded in it occur on this horizon in Morgan County. Impure limestone from this horizon has been utilized in a small way for road construction.

Ewing Limestone

The position of the Ewing limestone in Morgan County is on an average about 40 feet below the Ames limestone and 100 feet above the persistent Brush Creek beds. As this limestone is local in distribution and where present invariably thin and nodular, its economic importance is trifling.

Cambridge Limestone

The Cambridge limestone which reaches its thickest development in east central Muskingum County and west central Guernsey County is poorly represented in Morgan County as it consists for the most part of nodular fossiliferous limestone embedded in argillaceous shale. The areal distribution of the Cambridge in Morgan County is essentially the same as that of the Brush Creek which occurs about 28 feet below it.

Ames Limestone

The Ames limestone in Morgan County occurs above drainage along the valley of the East Branch of Sunday Creek in western Homer and western Deerfield townships, along the valley of Wolf Creek and its tributaries in eastern Deerfield Township, and along the Muskingum Valley from the north boundary of the county to Lowell in southwestern Malta Township. According to Condit the Ames in this county occurs generally as a single layer with a usual thickness of about 2 feet. [1] Locally near Tridelphia, Deerfield Township, the member thickens to as much as 4 feet. [2] The position of the Ames limestone is on an average about 165 feet below the Pittsburgh coal horizon.

The Ames limestone outcrops in good development along the valley of Kickapoo Creek in the northwest quarter of Section 15, Deerfield Township. The exposures in the creek bed where the stream crosses the north boundary of the section are described below.

		Ft.	In.
Shale, olive-colored		3	0
Limestone, gray, dense to crystalline, fossiliferous	Ames	1	6
Limestone, gray, to purplish gray, dense, fossiliferous	Ames	-	6
Shale, olive gray, arenaceous		2	0

Altitude 918 feet.

The Ames limestone at this locality having a thickness of 2 feet was sampled by R. E. Lamborn on July 11, 1944, for chemical analysis.

[1] *Condit, D. D., op. cit., p. 134.*

[2] *Condit, D. D., op. cit., p. 138.*

Sample No. 436

Chemical analysis of Ames limestone from outcrop along Kickapoo Creek, Section 15, Deerfield Township, Morgan County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	6.53
Alumina, Al_2O_3	1.00
Ferric oxide, Fe_2O_3	0.41
Ferrous oxide, FeO	0.59
Iron disulphide, FeS_2	0.04
Magnesium oxide, MgO	0.47
Calcium oxide, CaO	49.83
Sodium oxide, Na_2O	0.14
Potassium oxide, K_2O	0.09
Water, hydroscopic, H_2O-	0.06
Water, combined, H_2O+	0.41
Carbon dioxide, CO_2	39.48
Titanium dioxide, TiO_2	·0.05
Phosphorus pentoxide, P_2O_5	0.34
Sulphur trioxide, SO_3	0.07
Manganous oxide, MnO	0.53
Total	100.04

The mineral constituents in Sample No. 436 as determined by calculation (Lamborn) from the chemical analysis with per cent of each are as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	2.49
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.04
Silica, SiO_2	5.35
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.48
Ferrous carbonate, $FeO.CO_2$	0.95
Iron disulphide, FeS_2	0.04
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO.P_2O_5$	0.74
Calcium sulphate, $CaO.SO_3$	0.12
Calcium carbonate, $CaO.CO_2$	88.13
Magnesium carbonate, $MgO.CO_2$	0.98
Manganese carbonate, $MnO.CO_2$	0.86
Water, hydroscopic, H_2O-	0.06
Unbalanced components (excess CO_2, H_2O)	-0.25
Total	100.04

Summerfield Limestone

The Summerfield member in Morgan County consists of two or more thin discontinuous beds of gray to light buff limestone interstratified with clay shale which occur on an average from 45 to 50 feet below the Pittsburgh coal horizon. Although this member occurs in good thickness and purity in eastern Noble County and in eastern Guernsey County, it has no known economic importance in Morgan County.

Pittsburgh Limestone

The Pittsburgh limestone, which occurs close below the Pittsburgh coal, is the top member of the Conemaugh series. In Morgan County outcrops of this limestone horizon are present over a broad belt extending across the area from Homer and Marion townships on the south to Bloom and Bristol townships on the north. The member consists chiefly of calcareous clay and clay shale with nodules or a few thin beds of limestone.

Fishpot Limestone

The Fishpot is a persistent limestone member of the Monongahela series of Morgan County occurring in the interval between the Redstone coal below and the Fishpot coal above. Outcrops of this limestone are present near the tops of high hills and ridges in Homer, Union, Malta, and Bloom townships, but the regional dip of the beds to the southeast brings the outcrops to lower levels in Marion, Windsor, Penn, Meigsville, and Bristol townships. The upper part of the member consists of regular bedded layers of bluish to brownish gray, dense-textured limestone varying from a few inches to 5 feet in thickness, separated by thin calcareous shale partings. Below this upper zone calcareous shale becomes more prominent and the limestone layers tend to be thinner. The thickness of the member varies from two or three feet to more than 30 feet. Where a maximum thickness of the member is found, the limestone and shale composing it virtually fill the interval between the Redstone and Fishpot coals. A reduced thickness is generally accompanied by a replacement of the lower part by sandy shale or shaly sandstone. The Fishpot member is the chief source for limestone in Morgan County and quarries have operated in it at various places, in Marion, Union, Meigsville, and Bristol townships. The upper or more heavy bedded part of the Fishpot member is the stone generally quarried.

In the northeast quarter of Section 7, Bristol Township, the Fishpot limestone is quarried (1942) by Arthur Davis of McConnelsville on property owned by Everitt Thurley. The chief market for the stone is for road construction although small quantities are sold for agricultural limestone. The beds exposed in the quarry are described as follows:

		Ft.	In.
Coal and black shale, Fishpot		-	10
Shale, bluish gray, calcareous, with a few discontinuous limestone layers, not sampled	Fishpot	2	8
Limestone, bluish gray, somewhat brecciated, hard, tough, sampled	Fishpot	1	0
Shale, bluish gray, calcareous, not sampled	Fishpot	-	11
Limestone, light bluish gray, dense, compact, sampled	Fishpot	-	7
Shale, bluish gray, calcareous, not sampled	Fishpot	-	7
Limestone, light bluish gray, dense texture, somewhat brittle, sampled	Fishpot	5	0

Bottom of quarry. Altitude 940 feet.

The limestone at this locality having a total thickness of 6 feet 7 inches was sampled by R. E. Lamborn on June 9, 1942, for chemical analysis.

Sample No. 375

Chemical analysis of Fishpot limestone from quarry on Everitt Thurley property, Section 7, Bristol Township, Morgan County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	12.71
Alumina, Al_2O_3	2.73
Ferric oxide, Fe_2O_3	0.45
Ferrous oxide, FeO	1.97
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	5.63
Calcium oxide, CaO	37.56
Strontium oxide, SrO	0.05
Barium oxide, BaO	0.20
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	<0.01
Water, hydroscopic, H_2O-	0.30
Water, combined, H_2O+	1.85
Carbon dioxide, CO_2	35.42
Titanium dioxide, TiO_2	0.02
Phosphorus pentoxide, P_2O_5	0.04
Sulphur trioxide, SO_3	0.40
Manganous oxide, MnO	0.21
Carbon, organic, C	0.43
Hydrogen, organic, H	0.06
Total	100.05

The per cent of each of the compounds probably present in this sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.25
Silicates $Al_2O_3.2SiO_2.2H_2O$	6.66
Silica, SiO_2	9.49
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.53
Ferrous carbonate, $FeO.CO_2$	3.17
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO.P_2O_5$	0.09
Calcium sulphate, $CaO.SO_3$	0.44
Strontium sulphate, $SrO.SO_3$	0.09
Barium sulphate, $BaO.SO_3$	0.30
Calcium carbonate, $CaO.CO_2$	66.63
Magnesium carbonate, $MgO.CO_2$	11.77
Manganese carbonate, $MnO.CO_2$	0.34
Water, hydroscopic, H_2O-	0.30
Organic matter	0.49
Unbalanced components (excess CO_2, H_2O)	-0.52
Total	100.05

The Fishpot limestone has been quarried on a small scale for agricultural purposes on the Harvey Archer property in the southwest quarter of Section 18, Meigsville Township. The quarry is located along the lower slopes of a small valley tributary to Sherwood Run at an elevation of about 910 feet. A description of the exposures in the quarry and of overlying beds outcropping along the hillside is given in the section which follows:

		Ft.	In.
Limestone layer, light bluish gray, compact hard		2	0
Shale and covered		44	0
Coal, shaly, and black shale, Meigs Creek or No. 9		1	8
Covered interval		6	6
Shale, gray, arenaceous		1	0
Shale, argillaceous, bluish gray		1	0
Clay shale, dark, Fishpot coal horizon		-	2
Shale, bluish gray		1	8
Limestone, light bluish to brownish gray, dense texture, somewhat brittle, upper 12 inches mottled, lower 5 inches arenaceous, sampled	Fishpot	2	8
Shale, bluish gray, calcareous, not sampled	Fishpot	-	1 1/2
Limestone, light bluish to brownish gray, dense texture, brittle, sampled	Fishpot	1	6
Shale, bluish gray, calcareous, not sampled	Fishpot	-	4
Limestone, bluish to brownish gray, sampled	Fishpot	1	2
Covered interval		1	6
Bottom of quarry.			

The Fishpot limestone described in this section having a thickness of 5 feet 4 inches was sampled by R. E. Lamborn on June 10, 1942, for chemical analysis.

Sample No. 376

Chemical analysis of Fishpot limestone from quarry on Harvey Archer property, Section 18, Meigsville Township, Morgan County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	8.28
Alumina, Al_2O_3	2.05
Ferric oxide, Fe_2O_3	0.04
Ferrous oxide, FeO	0.86
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	4.40
Calcium oxide, CaO	43.84
Strontium oxide, SrO	<0.01
Barium oxide, BaO	0.09
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	<0.01

Water, hydroscopic, H_2O-	0.27
Water, combined, H_2O+	1.17
Carbon dioxide, CO_2	38.33
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.05
Sulphur trioxide, SO_3	0.07
Manganous oxide, MnO	0.13
Carbon, organic, C	0.42
Hydrogen, organic, H	0.05
Total	100.08

The per cent of each of the mineral compounds probably present has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.25
Silicates $Al_2O_3.2SiO_2.2H_2O$	4.94
Silica, SiO_2	5.87
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	1.39
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.01
Calcium phosphate, $3CaO.P_2O_5$	0.11
Calcium sulphate, $CaO.SO_3$	0.04
Barium sulphate, $BaO.SO_3$	0.14
Calcium carbonate, $CaO.CO_2$	78.11
Magnesium carbonate, $MgO.CO_2$	9.19
Manganese carbonate, $MnO.CO_2$	0.21
Water, hydroscopic, H_2O-	0.27
Organic matter	0.47
Unbalanced components (excess CO_2, H_2O)	-0.96
Total	100.08

The Fishpot limestone was formerly quarried near the top of the high knob on the William Wyner property in the south central part of Section 33, Union Township. The chief market for the stone was for road construction and repair although the dust and fine screenings were sold for agricultural lime. The exposures in the quarry are described by Wilber Stout as follows:

		Ft.	In.
Limestone, light, irregular	Fishpot	-	6
Shale	Fishpot	1	0
Limestone, light, irregular	Fishpot	1	8
Shale	Fishpot	1	4
Limestone, light, irregular		-	8
Shale		-	3
Limestone, light, irregular		-	4
Limestone		2	1

Bottom of quarry. Altitude, 1097 feet.

Samples of the prepared stone were collected by Wilber Stout on June 25, 1941, for chemical analysis. Sample No. 352 was taken from pile of No. 46 road stone, whereas Sample No. 353 was collected from pile of fines utilized for agricultural purposes.

Samples No. 352, 353

Chemical analysis of Fishpot limestone from quarry of William Wyner, Section 33, Union Township, Morgan County, Downs Schaaf, analysts

	No. 352 Size 46 road stone Per cent	No. 353 Fines Per cent
Silica, SiO_2	9.20	9.65
Alumina, Al_2O_3	1.95	2.25
Ferric oxide, Fe_2O_3	0.29	0.28
Ferrous oxide, FeO	0.25	0.26
Iron disulphide, FeS_2	0.03	0.04
Magnesium oxide, MgO	0.79	0.77
Calcium oxide, CaO	47.40	46.88
Strontium oxide, SrO	<0.01	<0.01
Barium oxide, BaO	<0.01	<0.01
Sodium oxide, Na_2O	0.02	0.03
Potassium oxide, K_2O	0.07	0.11
Water, hydroscopic, H_2O-	1.10	1.16
Water, combined, H_2O+	0.45	0.50
Carbon dioxide, CO_2	38.12	37.70
Titanium dioxide, TiO_2	0.14	0.14
Phosphorus pentoxide, P_2O_5	0.10	0.09
Sulphur, trioxide, SO_3	0.03	0.05
Manganous oxide, MnO	0.11	0.11
Carbon, organic, C	0.04	0.03
Total	100.09	100.05

The per cent of each of the various compounds probably present in Sample No. 352 as computed (Lamborn) from the chemical analysis is as follows:

		Per cent
Silicates	$(Na, K)_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$	0.84
	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	4.11
Silica, SiO_2		6.90
Hydrated ferric oxide, $2Fe_2O_3 \cdot 3H_2O$		0.34
Ferrous carbonate, $FeO \cdot CO_2$		0.40
Iron disulphide, FeS_2		0.03
Titanium dioxide, TiO_2		0.14
Calcium phosphate, $3CaO \cdot P_2O_5$		0.22
Calcium sulphate, $CaO \cdot SO_3$		0.05
Calcium carbonate, $CaO \cdot CO_2$		84.35
Magnesium carbonate, $MgO \cdot CO_2$		1.65
Manganese carbonate, $MnO \cdot CO_2$		0.18
Water, hydroscopic, H_2O-		1.10
Organic matter		0.04
Unbalanced components (excess CO_2, H_2O)		-0.26
Total		100.09

The per cent of each of the various compounds probably present in Sample No. 353 has been computed (Lamborn) from the chemical analysis.

		Per cent
Silicates	$(Na, K)_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$	1.30
	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	4.41
Silica, SiO_2		7.00
Hydrated ferric oxide, $2Fe_2O_3 \cdot 3H_2O$		0.33
Ferrous carbonate, $FeO \cdot CO_2$		0.42
Iron disulphide, FeS_2		0.04
Titanium dioxide, TiO_2		0.14
Calcium phosphate, $3CaO \cdot P_2O_5$		0.20
Calcium sulphate, $CaO \cdot SO_3$		0.08
Calcium carbonate, $CaO \cdot CO_2$		83.42

Magnesium carbonate, $MgO.CO_2$	1.61
Manganese carbonate, $MnO.CO_2$	0.18
Water, hydroscopic, H_2O-	1.16
Organic matter	0.03
Unbalanced components (excess CO_2, H_2O)	-0.27
Total	100.05

Benwood - Uniontown Limestone

The limestone members occurring in the 100-foot interval between the Meigs Creek and Uniontown coals are not clearly separated one from the other in Morgan County due to the general absence on the outcrop of the Fulton Green shale. Much of this interval in Morgan County is made up of calcareous shales and limestone beds interstratified. In general the limestone is more heavy bedded and the shale partings thinner in a zone occurring from 30 to 50 feet above the Meigs Creek coal whereas the upper part of the interval consists in large part of gray to pinkish shale with relatively fewer and thinner beds of limestone. The Benwood-Uniontown limestones have a wide distribution as outcrops occur in Bloom, Penn, Homer, Union, Bristol, Meigsville, Windsor, Center, and Manchester townships. These limestones are found high in the hills in Bloom, Malta, Penn, and Marion townships in the west central part of the county but their altitude decreases to the southeast for in Manchester and Center townships the thickest deposits of limestone occur less than 100 feet above the drainage levels of Dyes Fork and Olive Green Creek. The thickness of this limestone-shale series in Morgan County is approximately 100 feet. Quarries have been opened in these limestones at a few localities, but in general they have received less attention than the underlying Fishpot limestone.

In 1942 Mr. Harry Daugherty operated a limestone crusher along Scotts Run about 2 miles southwest of Stockport and about three-fourths of a mile south of west of the Ellis School, Windsor Township. The plant was supplied in part with limestone blocks gathered from the bed of the stream and in part with stone quarried along the bank of the stream near the mouth of a prominent tributary from the east. A description of the exposures along the creek is as follows:

	Ft.	In.
Shale and weathered material	5	0
Limestone, dark bluish gray, dense texture, tough, sampled	-	7
Limestone, dark bluish gray, irregular bedded, sampled	-	6
Limestone, light bluish to brownish gray, sampled	-	5
Limestone, gray, argillaceous, somewhat arenaceous, sampled	2	8
Shale, dark bluish gray, calcareous, not sampled	1	8
Limestone, dark bluish gray, dense texture, tough, sampled	-	9
Shale, calcareous, not sampled	-	1
Limestone, dark bluish gray, dense texture, sampled	-	5
Shale, calcareous, not sampled	-	1
Limestone, dark bluish gray, brecciated, sampled	-	5
Shale, calcareous, not sampled	-	1/2
Limestone, dark bluish, dense texture, somewhat impure, sampled	1	3

Shale, with limestone nodules, not sampled	2	0
Creek level. Altitude about 790 feet.		

The limestone exposed at this locality probably represents in part the Benwood member as the horizon of the Meigs Creek coal should occur less than 30 feet below creek level. The limestone beds described in the above section was sampled by R. E. Lamborn on June 10, 1942, for chemical analysis.

Sample No. 377

Chemical analysis of Benwood limestone from quarry operated by Harry Daugherty, near Ellis School, Windsor Township, Morgan County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	10.59
Alumina, Al_2O_3	2.51
Ferric oxide, Fe_2O_3	0.33
Ferrous oxide, FeO	0.50
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	7.06
Calcium oxide, CaO	39.95
Strontium oxide, SrO	<0.01
Barium oxide, BaO	0.10
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	<0.01
Water, hydroscopic, H_2O-	0.27
Water, combined, H_2O+	0.60
Carbon dioxide, CO_2	37.07
Titanium dioxide, TiO_2	0.02
Phosphorus pentoxide, P_2O_5	0.07
Sulphur trioxide, SO_3	0.55
Manganous oxide, MnO	0.09
Carbon, organic, C	0.36
Hydrogen, organic, H	0.04
Total	100.13

The per cent of each of the various compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.25
Silicates $Al_2O_3.2SiO_2.2H_2O$	6.10
Silica, SiO_2	7.63
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.39
Ferrous carbonate, $FeO.CO_2$	0.81
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO.P_2O_5$	0.15
Calcium sulphate, $CaO.SO_3$	0.85
Barium sulphate, $BaO.SO_3$	0.15
Calcium carbonate, $CaO.CO_2$	70.54
Magnesium carbonate, $MgO.CO_2$	14.75
Manganese carbonate, $MnO.CO_2$	0.14
Water, hydroscopic, H_2O-	0.27
Organic matter	0.40
Unbalanced components, (excess CO_2, H_2O)	-2.32
Total	100.13

Elm Grove Limestone

The stratigraphic position of the Elm Grove limestone is close above the Waynesburg coal. In Morgan County this limestone has no economic importance as it is generally wanting, its place being occupied with arenaceous shale or sandstone.

MORROW COUNTY

General Considerations

The bedrocks exposed at the surface or immediately underlying the glacial drift in Morrow County include the upper part of the Ohio shale, the Bedford shale, Berea sandstone, and the Cuyahoga sandstones and shales. The total thickness of beds cropping out in this county is estimated to be greater than 1,000 feet. Limestone is wanting on the outcrop. Below the Ohio shale is a series of limestones and dolomites in excess of 700 feet in thickness. The top of this series occurs at elevations above sea level ranging from approximately 800 feet in the northwestern part to 100 feet in the southeastern corner of the county.

MUSKINGUM COUNTY

General Considerations

Muskingum County comprises an area of 673 square miles surrounding the junction of the Muskingum and Licking rivers in the east central part of Ohio. Physiographically the county is situated entirely within the dissected Allegheny Plateau and most of it occurs in the unglaciated part. Glaciation has had little direct influence, therefore, in modifying the topography or obscuring the rock outcrops, as the east margin of the ice sheet just touched the west boundary of the county. Glacial outwash deposits of sand, gravel, and silt, however, occur along all the larger preglacial and interglacial valleys. The bedrocks which outcrop in Muskingum County are of the common sedimentary types. The total vertical thickness represented by these outcrops is approximately 1,230 feet. The rock section includes the upper part of the Mississippian system, the Pennsylvanian system, and the lower 50 feet of the Washington series of the Permian system. Beds of Mississippian age are confined to the lower slopes of the major valleys in the northwest part of the county and to the large valley extending east and west through Trinway. As a result of the regional southeast dip of the strata, these beds pass to the southeast beneath the younger and overlying Pennsylvanian series which form the chief outcrops in the area. The Permian strata are relatively small in areal extent for thick outcrops are confined to the hilltops in the southeast corner. A generalized section of the bedrocks exposed in Muskingum County is as follows: [1]

Generalized Section of Bedrocks Outcropping in Muskingum County

	Ft.	In.
Permian system		
Washington series		
Sandstone, shaly	3	0
Clay shale, red and yellow	7	0
Sandstone, some shale in upper part, Waynesburg	10	0

[1] *Stout, Wilber, Geology of Muskingum County: Geol. Survey Ohio Bull. 21, 1918.*

Clay shale, red	4	0
Limestone, blue, two beds with thin shale parting, Elm Grove	2	0
Clay shale, red and drab	27	0
Pennsylvanian system		
Monongahela series		
Coal, persistent, Waynesburg	1	0
Clay shale, red	27	0
Sandstone, massive, persistent, Gilboy	35	0
Shale, dark	1	0
Coal, thin, Uniontown or No. 10	2	0
Clay, calcareous	2	0
Limestone, thin to medium bedded, Uniontown	10	0
Clay shale with marly limestone and local deposits of shale and shaly sandstone	34	0
Limestone, thin to medium bedded, interstratified with clay shale and marly limestone, Benwood	47	0
Sandstone, thin or wanting, Sewickley	10	0
Shale and sandstone	19	10
Coal, with two shale partings, Meigs Creek or No. 9	4	2
Shale, generally red and calcareous	9	0
Limestone, thin to medium bedded, with clay partings, Fishpot	10	0
Shale, red, calcareous	5	0
Sandstone, local, Pomeroy	3	6
Coal, shaly, Redstone or No. 8a	-	6
Clay and shale, calcareous	2	0
Limestone, locally present, Redstone	4	0
Sandstone, local, Pittsburgh	16	0
Shale, dark, arenaceous	3	0
Coal, thin, persistent, Pittsburgh or No. 8	2	0
Conemaugh series		
Clay and clay shale with local deposits of marly limestone	7	0
Limestone, rather persistent, Pittsburgh	9	6
Clay shale, calcareous, mottled	3	0
Sandstone, generally shaly, Bellaire	5	0
Clay shale, with some marly limestone	12	0
Coal, local, Lower Little Pittsburgh	-	6
Clay shale, light to red, calcareous	11	0
Limestone layers, interbedded with clay shale, persistent, Summerfield	6	0
Clay shale, red, calcareous	8	0
Sandstone, generally shaly, local Connellsville	5	0
Clay shale, red, calcareous	12	0
Coal, poorly marked, Clarksburg	--	--
Limestone, locally present, interstratified with shale, Clarksburg	3	8
Clay shale, calcareous	31	0
Sandstone, locally present, Morgantown	6	0
Shale, drab, locally present	10	0

Clay shale, red	3	4
Limestone, persistent, Skelley	--	4
Clay shale, red	9	0
Shale and shaly sandstone	28	9
Limestone, very steady, fossiliferous, Ames	1	7
Shale and shaly sandstone	17	9
Coal, steady, Harlem	1	5
Clay, arenaceous	1	4
Clay shale, red and brown, Round Knob	16	6
Sandstone, locally present, Saltzburg	7	6
Coal, thin, local, Barton	--	6
Clay and shale	5	9
Limestone, fossiliferous, local, Ewing	--	8
Shale and shaly sandstone, gray	12	0
Sandstone, local, Cow Run	20	0
Shale, gray	1	4
Shale, black, with nodular limestone, Portersville	4	9
Coal, steady, Anderson	1	11
Clay and shale	3	9
Limestone, nodular, local, Bloomfield	1	5
Shale, generally gray	8	8
Limestone, somewhat nodular, Cambridge	1	11
Coal, poorly developed, Wilgus	--	4
Clay and shale	10	0
Sandstone, local, Buffalo	26	0
Limestone and shale, dark, fossiliferous, Brush Creek	3	11
Shale, gray	5	4
Coal, thin, shaly, patchy, Mason	--	3
Sandstone, irregular, Upper Mahoning	14	0
Coal, thin, persistent, Mahoning	--	5
Clay, light, arenaceous	3	9
Limestone, nodular, seldom present, Mahoning	--	3
Sandstone, local, Lower Mahoning	33	0
Allegheny series		
Coal, locally present, Upper Freeport or No. 7	2	6
Clay, arenaceous, and shale	6	0
Limestone, nodular, Upper Freeport	--	9
Clay and shale	2	3
Clay, part flinty, Bolivar	4	6
Sandstone, local, Upper Freeport	20	0
Shale, gray, arenaceous	10	0
Coal, Lower Freeport or No. 6a	--	6
Shale and clay	5	6
Limestone, nodular, local, Lower Freeport	--	6
Clay and clay shale	2	3
Sandstone, unsteady, Lower Freeport	25	0
Shale	12	0
Coal, two benches separated by a shale parting, Middle Kittanning or No. 6	3	9 1/2
Clay, arenaceous	4	0
Shale and sandstone	11	3
Coal, thin, Strasburg	--	1

Clay, flint and plastic, Oak Hill	4	8
Limestone, dark, ferruginous, nodular, Hamden	1	0
Shale, argillaceous	2	0
Coal, local, Lower Kittanning or No. 5	3	0
Clay, light, plastic	6	0
Shale and sandstone	3	3
Ore, nodular, local, Ferriferous	--	3
Limestone, often shaly near bottom, flinty at top, Vanport	8	6
Coal, with two shale partings, local, Clarion or No. 4a	7	2
Clay, arenaceous	2	4
Sandstone, local, Clarion	24	6
Limestone, persistent, Putnam Hill	3	0
Shale, dark	--	1
Coal, persistent, Brookville or No. 4	--	3
Pottsville series		
Clay, arenaceous	3	6
Sandstone, local, Homewood	16	8
Coal, thin, often wanting, Tionesta or No. 3b	--	9
Clay, light, plastic	3	6
Shale and sandstone with one ore bed	19	0
Limestone, black, flinty, Upper Mercer	1	5
Shale	--	6
Coal, with a thin shale parting, Bedford	1	4
Clay, arenaceous	4	0
Coal, thin, often wanting, Upper Mercer or No. 3a	--	6
Clay, arenaceous	2	6
Shale, with one thin ore bed	7	0
Limestone } Lower Mercer	2	2
Shale, calcareous } Lower Mercer	--	1
Limestone } Lower Mercer	1	4
Shale, dark	--	7
Coal, Middle Mercer	--	6
Clay, light, arenaceous	2	6
Shale and sandstone	8	0
Coal, local, Flint Ridge	--	5
Clay, flint, and plastic	3	10
Shale and sandstone	5	6
Limestone, flint, or ore, Boggs	1	2
Shale	1	0
Coal, locally present, Lower Mercer or No. 3	--	8
Clay, arenaceous	2	8
Shale and sandstone	23	6
Iron ore } Lowellville Poverty Run	--	4
Shale, calcareous } Lowellville Poverty Run	1	0
Limestone, gray } Lowellville Poverty Run	--	4
Shale and sandstone	5	0
Coal, local, Vandusen	1	0
Clay, arenaceous	1	6
Shale and sandstone	14	0
Coal, unsteady, Bear Run	--	6
Clay, arenaceous	2	4
Sandstone, local, Massillon	25	0

Coal, persistent, Quakertown or No. 2	1	8
Clay, arenaceous	2	0
Shale and sandstone	13	0
Coal, local, Anthony	--	6
Clay, arenaceous, seldom present, Sciotoville	3	0
Shale and shaly sandstone	21	0
Coal, local, Sharon or No. 1	--	6
Clay, arenaceous	2	0
Conglomerate, local, Sharon	3	0
Ore, locally present, Harrison	--	6
Mississippian system		
Limestone, thin to thick-bedded, light gray to light brown, with some thin shale interstratified, Maxville, maximum thickness	60	0
Shale and shaly sandstone, gray to buff, with scattered nodules of iron oxide, Logan, approximate thickness	170	0

As indicated in the generalized section, limestone deposits have been recognized at 26 different stratigraphic horizons in Muskingum County. The thickness of the solid limestone comprising the individual member or formation ranges from a few inches to a maximum at any one exposure of about 35 feet and the character varies from hard compact stone of high purity to impure, nodular, discontinuous deposits embedded in calcareous clay and clay shale. As indicated in the following pages many of the limestone members in this county have slight importance other than as stratigraphic horizon markers in the rock series. For their economic worth the most important limestones outcropping in Muskingum County are the Maxville, Lower Mercer, Putnam Hill, Vanport, Cambridge, Ames, and Fishpot.

In the rock series underlying the Maxville formation no limestones or dolomites are encountered in deep wells until the Middle Devonian series is reached at depths below sea level ranging from about 1,100 feet in the northwest corner to about 2,600 feet in the southeast corner of the county.

Maxville Limestone

The Maxville limestone reaches the surface in Muskingum County along the lower slopes of the valleys of Kent Run and Jonathan Creek in the western two-thirds of Newton Township and also along the westward slope of the valley of Poverty Run in Hopewell Township. The horizon of this formation is likewise above drainage in parts of Falls, Licking, and Jackson townships, but in these latter areas the limestone was removed by erosion preceding the deposition of strata of Pennsylvanian age. Along Poverty Run in Hopewell Township only a thin remnant of the formation remains, measuring a few feet in thickness. The thickest and best developed deposits on the outcrop are found in the Kent Run and Jonathan Creek areas in the vicinity of White Cottage and Fultonham. Here a maximum known thickness of about 35 feet is exposed above drainage. It has been quarried for many years in this area and has been utilized at various times for road metal, railroad ballast, agricultural limestone, building stone, concrete, Portland cement, and chemical limestone. [1] The stone is gray buff to brown in color, generally dense in texture, and thin to heavy bedded. In general the lower part of the formation tends to be more siliceous and more magnesian in composition than the upper part which in this area is a high calcium stone.

[1] *Stout, Wilber, op. cit., pp. 39-45.*

The Maxville limestone is being quarried extensively near Fultonham Station, Newton Township, by the Columbia Portland Cement Division of the Pittsburgh Plate Glass Company. The quarries are located in the southern part of Section 18 where, in the summer of 1941, a quarry face about 35 feet in height was being worked. The upper half of the exposure is a high calcium limestone whereas the lower half tends to be more dolomitic and more highly siliceous in composition. Limestone for agricultural purposes and for chemical uses has been produced from the upper or purer ledges whereas stone from the entire quarry face has been utilized in the production of Portland cement. A description of the exposures near the south end of the quarry is as follows:

	Ft.	In.
Limestone, gray to light brown tint, dense to finely crystalline. Layers vary from 4 inches to 1 foot in thickness, Sample No. 345	17	9
Limestone, brown, dense texture, flint-like fracture, Sample No. 346	6	5
Limestone, brown, dense texture, tough, somewhat laminated, Sample No. 347	2	0
Shale, dark, carbonaceous	1	3
Sandstone, fine-grained, calcareous, Sample No. 348	2	1
Limestone, dolomitic, buff, dense texture, laminated, Sample No. 349	5	9
Bottom of quarry.		

Five samples of limestone were cut from the quarry face for chemical analysis as described above. The samples were collected by R. E. Lamborn on June 12, 1941.

Samples No. 345, 346, 347, 348, 349

The chemical analyses of five samples of Maxville limestone from quarry of Columbia Portland Cement Division, Section 18, Newton Township, Muskingum County, Downs Schaaf, analyst

	No. 345 Per cent	No. 346 Per cent	No. 347 Per cent	No. 348 Per cent	No. 349 Per cent
Silica, SiO_2	1.65	4.82	11.40	73.70	13.82
Alumina, Al_2O_3	0.35	1.05	1.95	1.02	3.11
Ferric oxide, Fe_2O_3	0.02	0.02	0.02	0.02	0.02
Ferrous oxide, FeO	0.30	0.47	0.44	0.42	2.45
Iron disulphide, FeS_2	0.12	0.14	0.05	<0.01	0.05
Magnesium oxide, MgO	0.40	0.75	1.10	0.55	15.82
Calcium oxide, CaO	53.90	50.88	45.75	12.75	24.50
Strontium oxide, SrO	<0.01	<0.01	<0.01	<0.01	<0.01
Barium oxide, BaO	<0.01	<0.01	<0.01	<0.01	<0.01
Sodium oxide, Na_2O	0.02	0.03	0.05	<0.01	0.05
Potassium oxide, K_2O	0.07	0.14	0.29	0.02	0.28
Water, hydroscopic, H_2O-	0.09	0.25	0.70	0.25	0.55
Water, combined, H_2O+	0.07	0.27	0.61	0.25	0.95
Carbon dioxide, CO_2	42.88	40.95	37.17	10.80	37.90
Titanium dioxide, TiO_2	0.03	0.10	0.12	0.05	0.12
Phosphorus pentoxide	0.06	0.05	0.16	0.09	0.07

Sulphur trioxide, SO_3	0.03	0.05	0.10	0.02	0.15
Manganous oxide, MnO	0.07	0.05	0.06	0.05	0.12
Carbon, organic, C	0.02	0.04	0.06	0.03	0.05
Hydrogen, organic, H	--	--	--	--	--
Total	100.08	100.06	100.03	100.02	100.01

The per cent of each of the compounds probably present in Sample No. 345 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.84
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.06
Silica, SiO_2	1.24
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	0.48
Iron disulphide, FeS_2	0.12
Titanium dioxide, TiO_2	0.03
Calcium phosphate, $3CaO.P_2O_5$	0.13
Calcium sulphate, $CaO.SO_3$	0.05
Calcium carbonate, $CaO.CO_2$	96.04
Magnesium carbonate, $MgO.CO_2$	0.84
Manganese carbonate, $MnO.CO_2$	0.11
Water, hydroscopic, H_2O-	0.09
Organic matter	0.02
Unbalanced components (deficiency CO_2, H_2O)	+0.01
Total	100.08

The per cent of each of the compounds probably present in Sample No. 346 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.55
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.13
Silica, SiO_2	3.58
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	0.76
Iron disulphide, FeS_2	0.14
Titanium dioxide, TiO_2	0.10
Calcium phosphate, $3CaO.P_2O_5$	0.11
Calcium sulphate, $CaO.SO_3$	0.09
Calcium carbonate, $CaO.CO_2$	90.64
Magnesium carbonate, $MgO.CO_2$	1.57
Manganese carbonate, $MnO.CO_2$	0.08
Water, hydroscopic, H_3O-	0.25
Organic matter	0.04
Unbalanced components (deficiency CO_2, H_2O)	0.00
Total	100.06

The per cent of each of the compounds probably present in Sample No. 347 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	3.07
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.93
Silica, SiO_2	9.10
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	0.71
Iron disulphide, FeS_2	0.05
Titanium dioxide, TiO_2	0.12
Calcium phosphate, $3CaO.P_2O_5$	0.35
Calcium sulphate, $CaO.SO_3$	0.17
Calcium carbonate, $CaO.CO_2$	81.19

Magnesium carbonate, $MgO.CO_2$	2.30
Manganese carbonate, $MnO.CO_2$	0.10
Water, hydroscopic, H_2O-	0.70
Organic matter	0.06
Unbalanced components (deficiency CO_2, H_2O)	+0.16
Total	100.03

The per cent of each of the compounds probably present in Sample No. 348 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.17
Silicates $Al_2O_3.2SiO_2.2H_2O$	2.42
Silica, SiO_2	72.50
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	0.68
Iron disulphide, FeS_2	0.00
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO.P_2O_5$	0.20
Calcium sulphate, $CaO.SO_3$	0.03
Calcium carbonate, $CaO.CO_2$	22.54
Magnesium carbonate, $MgO.CO_2$	1.15
Manganese carbonate, $MnO.CO_2$	0.08
Water, hydroscopic, H_2O-	0.25
Organic matter	0.03
Unbalanced components (excess CO_2, H_2O)	-0.10
Total	100.02

The per cent of each of the compounds probably present in Sample No. 349 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	2.99
Silicates $Al_2O_3.2SiO_2.2H_2O$	4.94
Silica, SiO_2	10.16
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	3.95
Iron disulphide, FeS_2	0.05
Titanium dioxide, TiO_2	0.12
Calcium phosphate, $3CaO.P_2O_5$	0.15
Calcium sulphate, $CaO.SO_3$	0.26
Calcium carbonate, $CaO.CO_2$	43.39
Magnesium carbonate, $MgO.CO_2$	33.06
Manganese carbonate, $MnO.CO_2$	0.19
Water, hydroscopic, H_2O-	0.55
Organic matter	0.05
Unbalanced components (deficiency CO_2, H_2O)	+0.13
Total	100.01

In 1941 the Forbes Construction Company of Huntington, West Virginia, was quarrying the Maxville limestone along the valley of Kent Run in the southern part of Section 15, Hopewell Township. Here the limestone which forms the bed of the stream was quarried by power shovels and the stone was marketed for road construction and repair. A good exposure of the limestone occurs on the east side of the valley at the south edge of Section 15, where the following measurements were secured.

		Ft.	In.
Limestone, light chocolate brown, one layer, sampled	Maxville	--	4

Limestone, light chocolate brown, one layer, sampled	Maxville (cont.)	....	--	4
Limestone, light chocolate brown, one layer, sampled		....	1	1
Limestone, light chocolate brown, one layer, sampled		....	--	7
Limestone, light chocolate brown, one layer, sampled		....	--	6
Shale, bluish gray, calcareous, not sampled		....	--	1 1/2
Limestone, light chocolate brown, dense texture, one layer, sampled		....	--	8
Shale, calcareous, not sampled		....	--	3
Limestone, light chocolate brown, dense texture, one layer, sampled		....	--	8
Limestone, bluish to light chocolate brown, one layer, sampled........		....	1	1
Shale, dark bluish gray, calcareous, arenaceous, not sampled		....	--	6
Shale, bluish gray, argillaceous, not sampled		....	1	0

The limestone as described in the above section was sampled by R. E. Lamborn on June 31, 1941, for chemical analysis.

Sample No. 354

Chemical analysis of Maxville limestone from exposure at south edge of Section 15, Hopewell Township, Muskingum County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	5.29
Alumina, Al_2O_3	1.70
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO....................................	0.77
Iron disulphide, FeS_2	0.10
Magnesium oxide, MgO....................................	2.90
Calcium oxide, CaO	47.18

Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.04
Potassium oxide, K_2O	0.24
Water, hydroscopic, H_2O-	0.24
Water, combined, H_2O+	0.49
Carbon dioxide, CO_2	40.55
Titanium dioxide, TiO_2	0.07
Phosphorus pentoxide, P_2O_5	0.07
Sulphur trioxide, SO_3	0.17
Manganous oxide, MnO	0.14
Carbon, organic, C	0.03
Hydrogen, organic, H	--
Total	100.00

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	2.52
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.83
Silica, SiO_2	3.29
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.24
Iron disulphide, FeS_2	0.10
Titanium dioxide, TiO_2	0.07
Calcium phosphate, $3CaO.P_2O_5$	0.15
Calcium sulphate, $CaO.SO_3$	0.29
Calcium carbonate, $CaO.CO_2$	83.85
Magnesium carbonate, $MgO.CO_2$	6.06
Manganese carbonate, $MnO.CO_2$	0.23
Water, hydroscopic, H_2O-	0.24
Organic matter	0.03
Unbalanced components (deficiency CO_2, H_2O)	+0.08
Total	100.00

Other Analyses of the Maxville Limestone From Muskingum County, D. J. Demorest, Analyst

	1 Per cent	2 Per cent	3 Per cent	4 Per cent
Silica, SiO_2	3.20	3.40	23.24	6.59
Alumina, Al_2O_3	0.49	0.70	2.03	1.90
Ferric oxide, Fe_2O_3	1.10	2.60	1.20	1.40
Calcium oxide, CaO	51.80	50.50	37.38	44.43
Magnesium oxide, MgO	0.35	2.20	2.18	4.39
Sulphur, S	0.10	0.11	0.32	0.29
Phosphorus, P	0.027	0.018	0.02	0.02
Titanium dioxide, TiO_2	Trace	Trace	Trace	Trace

No. 1 Maxville limestone from quarry of Fultonham Stone Company near White Cottage. Geol. Survey Ohio Bull. 21, p. 42, 1918.

No. 2 Maxville limestone from Norton Dove property on Poverty Run, Hopewell Township. Geol. Survey Ohio Bull. 21, p. 42, 1918.

No. 3 Lower layers of Maxville limestone exposed along Kent Run, Newton Township. Approximate thickness, 20 feet. Geol. Survey Ohio Bull. 21, p. 44, 1918.

No. 4 Maxville limestone from J. C. Stine property on Kent Run near Opera. Geol. Survey Ohio Bull. 21, p. 44, 1918.

Maxville Limestone Below The Surface

From its outcrops along Kent Run and Jonathan Creek in the Fultonham-White Cottage area the Maxville limestone extends below drainage to the east and southeast. It is reported in the records of many wells drilled for oil and gas in eastern Newton Township, in Clay, Brush Creek, and Harrison townships, in northwestern Blue Rock Township, in southwestern Salt Creek Township, and southeastern Wayne Township. From Kent Run, Newton Township, the Maxville limestone is believed to extend to the north beneath the highlands in the south half of Hopewell Township. In that part of the county lying east of the Muskingum River and north of an east-west line extending through Chandlersville, well records indicate that the limestone is generally thin or wanting. Where present the limestone varies in thickness from a very few feet to a maximum of about 100. This variation is the resultant from possible differences in thickness of limestone originally laid down, modified by differences in the amount removed during the period of post-Mississippian erosion preceding the deposition of the Pennsylvanian sediments. In the southeastern part of Brush Creek Township including sections 3, 4, 9, 10, 15, 16, and 29 the thickness of the limestone encountered in wells varies from 50 feet to about 70 feet. Similar conditions occur in sections 14 and 30, Harrison Township. Over an elongated area extending from Section 19, Harrison Township, northeast to the Muskingum River and then north along the river nearly to Philo, the Maxville limestone is generally thin or wanting. Its depth along the river in this area varies from about 300 feet to 370 feet. The limestone occurs again in good thickness northeast of Philo in southwestern Salt Creek Township and the eastern part of Section 29, Wayne Township, where the records of 18 wells show variations ranging from 45 feet to 100 feet. In the south central part of Wayne Township the Maxville is generally wanting.

In order to test the possibilities of the Maxville limestone in an area of thick development within an economic shafting distance from the surface, the Engineering Experiment Station of Ohio State University in the spring of 1948 drilled a core hole through this limestone in Section 29, Wayne Township. The test hole was located on the Margaret E. McCord property on the south side of Manns Fork in the northeast corner of the southeast quarter of the section. The top of the Maxville was encountered at a depth of 302 feet (altitude, 443 feet) and the formation was passed through at a depth of about 378 feet. The core was logged by C. H. Bowen of the Station and by W. H. Smith and R. E. Lamborn of the Geological Survey. The core through the limestone was split and quartered, two quarters being utilized for two separate sets of samples for chemical analysis. One suite of samples as described below was analyzed by E. Chadbourn for the Geological Survey. The log of the core through the limestone is as follows:

	Thickness Ft.	Thickness In.	Total depth Ft.	Total depth In.
Mississippian system				
Maxville formation				
Limestone, light brownish gray to dark gray, dense to finely crystalline, hard, compact. Lower half somewhat shaly and with abundant fossils; upper half slightly carbonaceous, no fossils. Top 1-inch is a very compact, brownish gray, dense iron carbonate				

grading downward to limestone.[1] Sample No. 447	5	6	307	6
Shale, gray black to greenish black, argillaceous, calcareous; contains some lenses and irregular layers of dark gray argillaceous limestone; not sampled	5	8	313	2
Shale, dark gray black to brown, very carbonaceous and calcareous, somewhat sandy with a very small amount of fine silica; not sampled	-	2	313	4
Shale, gray, to dark greenish gray, highly siliceous, calcareous. It contains many grains of calcareous or dolomitic material which are subangular to well rounded; some may be iron carbonate concretions; many small crystals of pyrite. The upper 2 inches contains sub-angular quartz grains in abundance; not sampled	1	11	315	3
Shale, green to greenish black, argillaceous; with a few fossils; not sampled	1	4	316	7
Limestone, gray and greenish gray to brownish gray, dense, very argillaceous, with thin streaks of greenish gray shale. The upper 9 inches is irregular and nodular showing clay partings with slickensides; not sampled	2	4	318	11
Shale, gray black to greenish black, soft, argillaceous, calcareous, with thin lenses and layers of dark brownish gray, dense limestone; the lower 3 inches contains small subangular fragments of dark limestone; not sampled	1	11	320	10
Limestone, light brown to buff, slightly argillaceous, with a few paper-thin clay shale partings. A 2-inch layer of brownish flint occurs 4 inches above the base. Included in Sample No. 446	2	2	323	0
Limestone, gray to light brownish gray, dense, compact, tough, hard, with many paper-thin clay				

[1] *This ore is probably the time equivalent of the Harrison ore of basal Pottsville age.*

shale partings. It contains some local aggregates of very small transparent unidentified crystals. Included in Sample No. 446	3	2	326	2
Shale (70 per cent) and limestone (30 per cent). The shale is greenish gray to gray black, soft, argillaceous, calcareous, and brittle and occurs in zones paper-thin to 4 inches thick. It is interbedded with brownish gray, dense to microcrystalline, compact limestone. Not sampled	4	8	330	10
Limestone, gray to light brownish gray, dense to finely crystalline; beds range from 1/2 to 2 inches in upper part to 1 to 3 inches in lower portion. Bedding planes are marked by thin clay or carbonaceous partings and incipient stylolites. Less fossiliferous than underlying units. Included in Sample No. 445	5	0	335	10
Limestone, light to brownish gray, dense to finely crystalline, sparingly fossiliferous, with clay partings 1 to 3 inches apart. Some carbonaceous partings associated with incipient stylolitic surfaces. Included in Sample No. 445	15	2	351	0
Limestone, light gray to brownish gray, dense to finely crystalline, fossiliferous, with several thin calcareous, carbonaceous shale partings and a few thin carbon line partings. Sample No. 444	11	2	362	2
Limestone, gray, dense to finely crystalline, slightly fossiliferous, with green clay shale partings 1/8 inch to 2 inches thick occurring 3 inches to 1 foot apart. Partings contain grains and small angular fragments of limestone and some small quartz grains. Sample No. 443	8	5	370	7
Limestone, dolomitic, light to dark gray, brecciated, with fragments more dolomitic than matrix. Fragments are generally angular to subangular and are often bounded by vugs lined with tiny rhombohedral crystals. Blobs of green argillaceous material common in middle part. Contact with overlying unit is a stylolitic zone. Included in Sample No. 442	6	0	376	7

Limestone, dolomitic, light gray, dense to finely granular, with blobs and streaks of greenish clay. Many cavities lined with small crystals. Included in Sample No. 442	1	8	378	3
Logan formation				
Sandstone, gray to gray green, very fine-grained, micaceous, with thin shale streaks interbedded. Pyrite common. The upper 2 inches is greenish shale containing small, well rounded, and etched quartz sand grains. Not sampled	7	0	385	3

Samples No. 342 to 347 Inclusive

Chemical analyses of Maxville limestone from a core hole test drilled on the Margaret E. McCord property, Section 29, Wayne Township, Muskingum County, E. Chadbourn, analyst

	Sample No. 442 7 ft. 8 in. Per cent	Sample No. 443 8 ft. 5 in. Per cent	Sample No. 444 11 ft. 2 in. Per cent	Sample No. 445 20 ft. 2 in. Per cent	Sample No. 446 5 ft. 4 in. Per cent	Sample No. 447 5 ft. 6 in. Per cent
Silica, SiO_2	5.73	11.03	4.60	4.58	9.59	19.19
Alumina, Al_2O_3	1.09	2.54	1.19	1.17	1.11	3.00
Ferric oxide, Fe_2O_3	0.23	0.20	0.06	0.11	0.28	0.26
Ferrous oxide, FeO	2.40	0.81	0.50	0.45	1.08	2.95
Iron disulphide, FeS_2	0.04	0.19	0.07	0.04	0.04	0.82
Magnesium oxide, MgO	16.76	2.47	2.02	1.48	4.26	2.94
Calcium oxide, CaO	29.59	43.88	49.68	50.50	43.50	35.64
Sodium oxide, Na_2O	0.22	0.11	0.12	0.06	0.24	0.16
Potassium oxide, K_2O	0.35	0.60	0.28	0.28	0.07	0.59
Water, hydroscopic, H_2O-	0.05	0.15	0.08	0.05	0.10	0.24
Water, combined, H_2O+	0.22	0.63	0.41	0.27	0.22	0.97
Carbon dioxide, CO_2	42.65	37.04	40.97	40.99	39.11	32.29
Titanium dioxide, TiO_2	0.06	0.14	0.07	0.06	0.06	0.21
Phosphorus pentoxide, P_2O_5	0.03	0.01	0.01	0.05	0.03	0.14
Sulphur trioxide, SO_3	0.14	0.08	0.10	0.05	0.08	0.15
Manganous oxide, MnO	0.17	0.04	0.03	0.04	0.10	0.26
Total	99.73	99.92	100.19	100.18	99.87	99.81

The per cent of each of the compounds present in samples as calculated (Lamborn) from the chemical analyses is essentially as follows:

	Sample No. 442	Sample No. 444	Sample No. 445	Sample No. 446
Silica and hydrated aluminum silicates of sodium and potassium	7.57	6.59	6.34	11.18
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.27	0.07	0.13	0.33
Ferrous carbonate, $FeO.CO_2$	3.87	0.81	0.73	1.74
Iron disulphide, FeS_2	0.04	0.07	0.04	0.04
Titanium dioxide, TiO_2	0.06	0.07	0.06	0.06
Calcium phosphate, $3CaO.P_2O_5$	0.07	0.02	0.11	0.06

Calcium sulphate, $CaO.SO_3$	0.24	0.17	0.09	0.14
Calcium carbonate, $CaO.CO_2$	52.57	88.52	89.96	77.48
Magnesium carbonate, $MgO.CO_2$	35.03	4.22	3.09	8.90
Manganese carbonate, $MnO.CO_2$	0.27	0.05	0.06	0.16
Water, hydroscopic, H_2O-	0.05	0.08	0.05	0.10
Unbalanced components (excess CO_2, H_2O)	-0.31	-0.48	-0.48	-0.32
Total	99.73	100.19	100.18	99.87

	Sample No. 443	Sample No. 447
Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	6.43	6.96
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.13	0.75
Silica, SiO_2	8.04	15.66
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.23	0.30
Ferrous carbonate, $FeO.CO_2$	1.30	4.75
Iron disulphide, FeS_2	0.19	0.82
Titanium dioxide, TiO_2	0.14	0.21
Calcium phosphate, $3CaO.P_2O_5$	0.02	0.31
Calcium sulphate, $CaO.SO_3$	0.14	0.25
Calcium carbonate, $CaO.CO_2$	78.20	63.13
Magnesium carbonate, $MgO.CO_2$	5.16	6.14
Manganese carbonate, $MnO.CO_2$	0.06	0.42
Water, hydroscopic, H_2O-	0.15	0.24
Unbalanced components (excess CO_2, H_2O)	-0.27	-0.13
Total	99.92	99.81

Lowellville (Poverty Run) Limestone

The Lowellville limestone member is best developed in Muskingum County in Hopewell, Falls, and Washington townships where it may consist of thin limestone or limestone overlain with shale and iron ore. At no place in Ohio is this member known to occur in sufficient thickness and purity to be of economic interest.

Boggs Limestone

The Boggs limestone, which occurs on an average about 20 feet below the Lower Mercer limestone in Muskingum County, is thin in development and is generally highly siliceous and ferruginous in composition. Its value as a source of limestone is trifling.

Lower Mercer Limestone

The distribution of this member above drainage in Muskingum County includes parts of every township west of a line drawn from Adams on the north to Newton on the south. Over this field of outcrops the Lower Mercer is not known to be wanting through lack of deposition and only in small local areas has its horizon been replaced by sandstone. The average thickness of the member according to Stout is about 3 feet 7 inches. [1] Excluding a shaly phase which in places forms the top of the member, the average thickness of the heavy bedded portion is between 2 feet

[1] *Stout, Wilber, Geology of Muskingum County: Geol. Survey Ohio Bull. 21, p. 89, 1918.*

and 2 feet 6 inches. The limestone occurs in best development in Muskingum, Madison, Cass, and Jackson townships. Although the thickness of the Lower Mercer limestone precludes the possibility of any large quarry operations, nevertheless its chemical and physical qualities are such that the stone offers possibilities as a source of limestone for local needs.

The following section was secured by Wilber Stout in 1916 along Beech Run in eastern Muskingum Township:

		Ft.	In.
Sandstone, shaly		11	0
Limestone, shaly	Lower Mercer	--	6
Limestone, hard	Lower Mercer	--	7
Limestone, shaly	Lower Mercer	--	5
Limestone	Lower Mercer	2	6
Shale, dark		-	4
Coal, bony, Middle Mercer		-	9
Clay and clay-bonded sandstone		3	6

A sample of the Lower Mercer limestone from exposures along Beech Run was collected by Wilbur Stout and analyzed by D. J. Demorest with the following results: [1]

Sample No. 1004

Chemical analysis of Lower Mercer limestone from outcrops along Beech Run, Muskingum Township, Muskingum County, D. J. Demorest, analyst

	Per cent
Silica, SiO_2	8.59
Alumina, Al_2O_3	1.50
Ferric oxide, Fe_2O_3	1.59
Calcium carbonate, $CaO.CO_2$	83.36
Magnesium carbonate, $MgO.CO_2$	2.12
Titanium dioxide, TiO_2	0.05
Phosphorus pentoxide, P_2O_5	0.25
Sulphur, S	0.75
Total	98.21

The shaly limestone phase of the Lower Mercer is well developed near Fairview School in Section 7, Jackson Township. The following section is a description of exposures along the road near the crest of the high knob one-half mile southeast of this school.

	Ft.	In.
Shale, gray, sandy	3	0
Limestone, dark bluish gray to black, shaly, fossiliferous, Lower Mercer	8	8
Bottom of exposure.		

The 8 feet 8 inches of shaly limestone representing the Lower Mercer at this locality was sampled for chemical analysis on June 27, 1944, by R. E. Lamborn.

Sample No. 434

Chemical analysis of Lower Mercer limestone from outcrop southeast Section

[1] *Stout, Wilber, op. cit. p. 89*

7, Jackson Township, Muskingum County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	47.73
Alumina, Al_2O_3	3.28
Ferric oxide, Fe_2O_3	0.81
Ferrous oxide, FeO	0.63
Iron disulphide, FeS_2	0.09
Magnesium oxide, MgO	0.46
Calcium oxide, CaO	24.55
Sodium oxide, Na_2O	0.06
Potassium oxide, K_2O	0.63
Water, hydroscopic, H_2O-	0.26
Water, combined, H_2O+	1.25
Carbon dioxide, CO_2	19.32
Titanium dioxide, TiO_2	0.10
Phosphorus pentoxide, P_2O_5	0.20
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.05
Total	99.46

The per cent of each of the chief mineral components in Sample No. 434 as calculated (Lamborn) from the chemical analysis is given below.

Silicates $(Na, K)_2O, 3Al_2O_3 . 6SiO_2 . 2H_2O$	6.06
Silicates $Al_2O_3 . 2SiO_2 . 2H_2O$	2.37
Silica, SiO_2	43.87
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.95
Ferrous carbonate, $FeO. CO_2$	1.01
Iron disulphide, FeS_2	0.09
Titanium dioxide, TiO_2	0.10
Calcium phosphate, $3CaO. P_2O_5$	0.44
Calcium sulphate, $CaO. SO_3$	0.07
Calcium carbonate, $CaO. CO_2$	43.14
Magnesium carbonate, $MgO. CO_2$	0.96
Manganese carbonate, $MnO. CO_2$	0.08
Water, hydroscopic, H_2O-	0.26
Unbalanced components (deficiency CO_2, H_2O)	+0.06
Total	99.46

Upper Mercer Limestone

The outcrops of the Upper Mercer member in Muskingum County have essentially the same areal extent as those of the Lower Mercer as the two horizons are separated by an interval which averages only about 20 feet. In this county the Upper Mercer consists chiefly of black flint or black flinty limestone having an average thickness on the outcrop of about 1 foot 5 inches. This flinty phase is well developed on the Harrison Drumm property along Drumm Run at the west edge of Section 14, N., Hopewell Township. The rock exposures along Drumm Run are described by Wilber Stout as follows:

		Ft.	In.
Flint, light		2	0
Shale, weathered	Vanport	1	0
Limestone, siliceous, sparingly fossiliferous	Vanport	-	10
Covered	Vanport	1	0

Limestone, siliceous, thin-bedded, fossiliferous	Vanport (cont.)	15	0
Covered		6	0
Shale		19	0
Limestone, blue, fossiliferous, Putnam Hill		1	2
Shale		-	2
Coal, Brookville		-	1
Clay, light, siliceous		3	0
Sandstone, light, clay-bonded		5	0
Clay, dark, flint		1	0
Clay, light, plastic		2	0
Covered		5	0
Shale		2	0
Covered		4	0
Flint, black, irregular, Upper Mercer		1	0
Shale		-	4
Coal, bony, cannel nature		1	0
Clay, siliceous		1	8
Shale, sandy		6	0
Sandstone, massive		30	0

The Upper Mercer limestone member at this locality was sampled for chemical analysis in 1936 by R. A. Schoenlaub of the State Highway Testing Laboratories.

Sample No. 82

Chemical analysis of Upper Mercer member from outcrops on Drumm Run, Section 14 N., Hopewell Township, Muskingum County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	95.33
Alumina, Al_2O_3	0.29
Ferric oxide, Fe_2O_3	1.01
Ferrous oxide, FeO	1.14
Iron disulphide, FeS_2	0.05
Magnesium oxide, MgO	0.01
Calcium oxide, CaO	0.40
Sodium oxide, Na_2O	0.05
Potassium oxide, K_2O	0.09
Water, hydroscopic, H_2O-	0.27
Water, combined, H_2O+	0.44
Carbon dioxide, CO_2	0.74
Titanium dioxide, TiO_2	0.02
Phosphorus pentoxide, P_2O_5	0.14
Sulphur trioxide, SO_3	<0.01
Manganous oxide, MnO	0.04
Carbon, organic	0.22
Hydrogen, organic	0.03
Total	100.27

The per cent of the various mineral constituents in the sample as computed (Lamborn) from the chemical analysis is as follows:

Silica with less than 2 per cent of hydrated aluminum silicates of sodium and potassium	96.03
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	1.18

Ferrous carbonate, $FeO.CO_2$	1.84
Iron disulphide, FeS_2	0.05
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO.P_2O_5$	0.31
Calcium carbonate, $CaO.CO_2$	0.42
Magnesium carbonate, $MgO.CO_2$	0.02
Manganese carbonate, $MnO.CO_2$	0.06
Water, hydroscopic, H_2O-	0.27
Organic matter	0.25
Unbalanced components (excess CO_2)	-0.18
Total	100.27

Putnam Hill Limestone

The field of outcrops of the Putnam Hill limestone in Muskingum County includes parts of every township west of the Muskingum River except Harrison and also small areas in Wayne, Washington, Madison and Adams townships east of the river. The thickness of the limestone on the outcrop varies from a few inches to 6 feet with an average of about 3 feet. [1] Areas of thick development include the eastern part of Newton Township and the eastern part of Springfield Township, the highland areas south of Mt. Sterling in Hopewell Township, the highland areas northeast of Mt. Sterling in Hopewell Township and northwestern Falls Township, the eastern part of Muskingum Township, the northern part of Washington Township, and the region of Highland Ridge and Irish Ridge in Cass Township. The Putnam Hill in these areas is typical in its lithologic characteristics. Impurities in the form of nodules of dark flint are found embedded in the limestone in some localities, but it is not constant and is never a conspicuous element in the Putnam Hill in this county. In former years this stone was quarried at many places along the outcrop and utilized for various purposes among which was limestone for furnace flux, for mortar and plaster, and for agricultural lime. The high carbonate content of the Putnam Hill limestone renders it well suited for agricultural needs but, with the improved means of transportation, it has fallen into disuse in Muskingum County in recent years in favor of the thicker and somewhat purer Maxville limestone.

The following measurements of outcrops along Beech Run in eastern Muskingum Township were made by Wilber Stout in 1916:

	Ft.	In.
Shale, gray, arenaceous	20	0
Limestone, Putnam Hill	4	4
Shale	-	1
Coal, Brookville	-	11
Clay and covered	4	6
Sandstone, gray, shaly	10	0

The Putnam Hill limestone was sampled along Beech Run by Wilbur Stout in 1916 and the sample was analyzed by D. J. Demorest. [2]

Sample No. 1005

Chemical analysis of Putnam Hill limestone from outcrop along Beech Run, Muskingum Township, Muskingum County, D. J. Demorest, analyst

[1] *Stout, Wilber, op. cit. p. 128.*

[2] *Stout Wilbur, op. cit., p. 136.*

Silica, SiO_2	2.25
Alumina, Al_2O_3	0.97
Ferric oxide, Fe_2O_3	1.10
Calcium carbonate, $CaO.CO_2$	92.32
Magnesium carbonate, $MgO.CO_2$	2.04
Titanium dioxide, TiO_2	0.05
Phosphorus pentoxide, P_2O_5	0.07
Sulphur, S	0.16
Total	98.96

The Putnam Hill limestone is present in good thickness and development along the high ridge in Cass Township just west of Dresden. Exposures along the public road about one-half mile east of the Elberson School are described as follows:

	Ft.	In.
Shale and covered	-	-
Limestone, bluish gray, generally dense and compact, Putnam Hill	4	1
Shale, buff, weathered	-	8
Coal and black shale, Brookville or No. 4	-	3
Clay, buff	3	4

On July 29, 1943, the Putnam Hill limestone was sampled by R. E. Lamborn for chemical analysis.

Sample No. 403

Chemical analysis of Putnam Hill limestone from outcrop along road, one-half mile east of Elberson School, Cass Township, Muskingum County, E. Chadbourn, analyst

Silica, SiO_2	1.89
Alumina, Al_2O_3	0.64
Ferric oxide, Fe_2O_3	0.24
Ferrous oxide, FeO	0.62
Iron disulphide, FeS_2	0.24
Magnesium oxide, MgO	0.78
Calcium oxide, CaO	52.40
Sodium oxide, Na_2O	0.05
Potassium oxide, K_2O	0.13
Water, hydroscopic, H_2O-	0.09
Water, combined, H_2O+	0.33
Carbon dioxide, CO_2	42.21
Titanium dioxide, TiO_2	0.03
Phosphorus pentoxide, P_2O_5	0.05
Sulphur trioxide, SO_3	0.08
Manganous oxide, MnO	0.12
Total	99.90

The per cent of each of the chief mineral components in the sample, as computed (Lamborn) from the chemical analysis, is as follows:

Silica and hydrated aluminum silicates of sodium and potassium	3.00
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.28
Ferrous carbonate, $FeO.CO_2$	1.00
Iron disulphide, FeS_2	0.24
Titanium dioxide, TiO_2	0.03
Calcium phosphate, $CaO.P_2O_5$	0.11

Calcium sulphate, $CaO.SO_3$	0.14
Calcium carbonate, $CaO.CO_2$	93.32
Magnesium carbonate, $MgO.CO_2$	1.63
Manganese carbonate, $MnO.CO_2$	0.19
Water, hydroscopic, H_2O-	0.09
Unbalanced components (excess CO_2)	-0.13
Total	99.90

Vanport Limestone

The Vanport limestone in Muskingum County is variable in lithologic character as it may consist in different localities of beds of flint underlain with shaly limestone, flinty limestone, calcareous flint, or calcareous shale. Outcrops of the limestone phase are confined in large part to the high hills and ridges in Hopewell and southern Licking townships, to the Highland Ridge area in Cass Township, and to small local patches along Symmes Creek in southern Madison Township. In these areas of outcrop the limestone varies from a few inches to 25 feet in thickness. It is generally light to dark bluish gray in color, somewhat shaly in structure, and highly siliceous in composition.

Near Gratiot in Hopewell Township the limestone phase of the Vanport member is well developed. Here it was formerly quarried and the stone utilized in concrete and for road construction. A description of the rock exposures in the old quarry located on the James McQuigg property in the northeast quarter of Section 5 is as follows:

	Ft.	In.
Soil and mantle rock. Estimated thickness	10	0
Limestone, light bluish to light brownish gray, dense, hard, siliceous or flinty. Layers vary from 2 inches to 1 foot thick, Vanport	6	0
Bottom of quarry.		

A sample of the 6-foot ledge of Vanport limestone exposed in this quarry was secured by R. E. Lamborn on Aug. 9, 1943, for chemical analysis.

Sample No. 404

Chemical analysis of Vanport limestone from abandoned quarry, Section 5, Hopewell Township, Muskingum County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	42.05
Alumina, Al_2O_3	3.24
Ferric oxide, Fe_2O_3	0.54
Ferrous oxide, FeO	0.60
Iron disulphide, FeS_2	0.07
Magnesium oxide, MgO	0.41
Calcium oxide, CaO	28.40
Sodium oxide, Na_2O	0.24
Potassium oxide, K_2O	0.61
Water, hydroscopic, H_2O-	0.16
Water, combined, H_2O+	0.87
Carbon dioxide, CO_2	22.44
Titanium dioxide, TiO_2	0.17
Phosphorus pentoxide, P_2O_5	0.12

Sulphur trioxide, SO_3	0.03
Manganous oxide, MnO	0.10
Total	100.05

The per cent of each of the various mineral components as computed (Lamborn) from the chemical analysis is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	8.12
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.19
Silica, SiO_2	38.23
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.63
Ferrous carbonate, $FeO.CO_2$	0.97
Iron disulphide, FeS_2	0.07
Titanium dioxide, TiO_2	0.17
Calcium phosphate, $3CaO, P_2O_5$	0.26
Calcium sulphate, $CaO.SO_3$	0.05
Calcium carbonate, $CaO.CO_2$	50.40
Magnesium carbonate, $MgO.CO_2$	0.86
Manganese carbonate, $MnO.CO_2$	0.16
Water, hydroscopic, H_2O-	0.16
Unbalanced components (excess CO_2, H_2O)	-0.22
Total	100.05

Near the Dutch School in Cass Township the Vanport is represented by a thick bed of gray limestone of exceptional purity for this county. A measurement of the exposures recorded by Wilber Stout is as follows:

	Ft.	In.
Limestone, gray, nodular, fossiliferous, Hamden	2	0
Clay and covered, Lower Kittanning horizon	5	0
Shale and covered, with siliceous limestone beds in interval	16	0
Limestone, fossiliferous, Vanport	4	0
Clay, shale, and covered	9	0
Shale, gray, parts arenaceous	25	9
Limestone, blue, nodular, fossiliferous, Putnam Hill	-	8
Shale, calcareous, fossiliferous	-	3

A sample of the Vanport limestone was collected near the Dutch School by Wilber Stout in 1917 and was analyzed by D. J. Demorest.[1]

Sample No. 1006

Chemical analysis of Vanport limestone from outcrop near Dutch School, Cass Township, Muskingum County, D. J. Demorest, analyst

	Per cent
Silica, SiO_2	1.59
Alumina, Al_2O_3	0.55
Ferric oxide, Fe_2O_3	1.05
Calcium oxide, CaO	53.90
Magnesium oxide, MgO	0.54
Sulphur, S	0.25
Phosphorus, P	0.059
Titanium dioxide, TiO_2	Trace

[1] *Stout, Wilber, op. cit., pp. 163-164.*

The approximate mineral composition of such a limestone as determined by calculation (Stout) can be expressed as follows:

	Per cent
Clay, $Al_2O_3 . 2SiO_2 . 2H_2O$	1.39
Silica, SiO_2	0.94
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.86
Iron disulphide, FeS_2	0.47
Titanium dioxide, TiO_2	Trace
Calcium phosphate, $3CaO. P_2O_5$	0.31
Calcium carbonate, $CaO. CO_2$	95.95
Magnesium carbonate, $MgO. CO_2$	1.13
Total	101.05

Hamden Limestone

The Hamden member in Muskingum County may consist of hard, dark, somewhat nodular limestone, of thin nodular iron ore, or of a mixture of these two types. The thickness varies from a few inches to a maximum of about 3 feet. This member is widely distributed on the outcrop in the western and northern halves of the county but it is probably best developed in Harrison, Hopewell, Falls, Wayne, Washington, Muskingum, and Cass townships. The best known deposits of the limestone phase of the Hamden are found along the high ridge known as The Highlands in southern Cass Township. A record of the exposures along this ridge near the Elberson School made by Wilber Stout in 1916 is as follows:

	Ft.	In.
Limestone, nodular, gray, fossiliferous, Hamden	3	0
Clay, light, Middle Kittanning	5	0
Shale	10	0
Limestone, Vanport	2	0

The Hamden limestone was sampled in Section 14 near the Elberson School by Wilber Stout and the sample was analyzed by D. J. Demorest. [1]

Sample No. 1007

Chemical analysis of Hamden limestone from outcrop, Section 14, Cass Township, Muskingum County, D. J. Demorest, analyst

	Per cent
Silica, SiO_2	1.86
Alumina, Al_2O_3	0.52
Ferric oxide, Fe_2O_3	0.82
Calcium oxide, CaO	53.68
Magnesium oxide, MgO	0.76
Sulphur, S	0.15
Phosphorus, P	0.039
Titanium dioxide, TiO_2	Trace

The approximate mineral composition of the sample as determined by calculation (Stout) from the chemical analysis is as follows:

[1] *Stout, Wilber, op. cit., p. 177.*

	Per cent
Clay, $Al_2O_3 . 2SiO_2 . 2H_2O$	1.31
Silica, SiO_2	1.25
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.74
Iron disulphide, FeS_2	0.28
Titanium dioxide, TiO_2	Trace
Calcium phosphate, $3CaO. P_2O_5$	0.20
Calcium carbonate, $CaO. CO_2$	95.66
Magnesium carbonate, $MgO. CO_2$	1.60
Total	101.04

Lower Freeport Limestone

The Lower Freeport is best represented in this county by a thin bed of limestone associated with the Lower Freeport clay and outcropping over small local areas in Harrison, Brush Creek, Perry and Washington townships. No economic importance can be attached to the Lower Freeport limestone in Muskingum County. For an analysis of this limestone see Sample No. 1000 secured in Columbiana County.

Upper Freeport Limestone

The Upper Freeport limestone is best represented on the outcrop in Muskingum County in Clay, Newton, Brush Creek, Harrison, Wayne, Perry, and Monroe townships although it has been recognized in Salt Creek, Bluerock, Salem, Adams, and Highland townships. The position of the limestone is on an average about 7 feet below the Upper Freeport coal. Its mode of occurrence is typical in that it may be represented by nodules or well defined layers. Over small areas it varies from 1 to 2 feet in thickness. For an analysis of the Upper Freeport limestone see Sample No. 1001, secured in Columbiana County.

Mahoning Limestone

The Mahoning limestone has been recognized at only a few places in Harrison, Bluerock, Perry, and Salem townships where it is represented by small nodular limestone embedded in the lower part of the Mahoning clay. No economic importance can be attached to this limestone.

Brush Creek Limestone

The Brush Creek beds, which consist of thin layers of dark carbonaceous limestone or gray flinty limestone more or less interstratified with dark calcareous shale, outcrops at a number of places in Clay, Brush Creek, Harrison, Bluerock, Salt Creek, Perry, and Wayne townships. In the northeastern part of the county where this member is due above drainage, its horizon is generally occupied by sandstone. The limestone facies probably has its best development in southern Clay Township and southern Brush Creek Township, where in places the limestone approaches 10 feet in thickness but tends to be highly siliceous and impure in composition. The stratigraphic position of the Brush Creek in Muskingum County is on an average about 57 feet above the Upper Freeport coal. For an analysis of the Brush Creek limestone in its field of best development in Ohio see sections of this report dealing with Gallia and Lawrence counties.

Cambridge Limestone

In this county the position of the Cambridge limestone is on an average about 107 feet above the base of the Conemaugh series or the top of the Upper Freeport coal. The field of outcrops of this limestone includes parts of every township east of a line extending from eastern Clay Township to eastern Adams Township with the exception of Rich Hill and Meigs townships in the southeastern part. In Clay, Brush Creek, Harrison, Bluerock, Wayne, and Salt Creek townships the Cambridge tends to be nodular, discontinuous, and impure, although over small areas a thickness of 3 to 4 feet may occur. It is more continuous in Perry, Union, Highland, Adams, and Monroe townships where it varies in thickness from 2 feet to as much as 12 feet. This limestone reaches its maximum development in southern Highland Township and in eastern Union Township but in these areas it tends to be highly siliceous in composition. The Cambridge limestone has been quarried at several places in the vicinity of New Concord and utilized chiefly for road metal.

An outcrop of the Cambridge limestone at the railroad cut at New Concord where it measures 8 feet in thickness was sampled by R. E. Lamborn in 1917 for chemical analysis. The sample was analyzed by D. J. Demorest. [1]

Sample No. 1008

Chemical analysis of Cambridge limestone from outcrop at New Concord, Union Township, Muskingum County, D. J. Demorest, analyst

	Per cent
Silica, SiO_2	33.75
Alumina, Al_2O_3	4.01
Ferric oxide, Fe_2O_3	2.23
Calcium oxide, CaO	31.61
Magnesium oxide, MgO	0.78
Sulphur, S	0.079
Phosphorus, P	0.055
Titanium dioxide, TiO_2	0.22

Expressed in terms of the per cent of the various mineral compounds present, the results are as follows:

Clay, $Al_2O_3 . 2SiO_2 . 2H_2O$	10.15
Silica, SiO_2	29.03
Iron disulphide, FeS_2	0.15
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	2.49
Titanium dioxide, TiO_2	0.22
Calcium phosphate, $3CaO . P_2O_5$	0.28
Calcium carbonate, $CaO . CO_2$	56.18
Magnesium carbonate, $MgO . CO_2$	1.64
Total	100.14

During the summer of 1941 the Cambridge limestone was being quarried for road stone on the J. A. Dixon property in the southeast quarter of Section 24, Highland Township. The stone is irregularly bedded and very arenaceous in character. A description of the exposures is given below.

[1] *Stout, Wilber, op. cit., p. 241-242.*

	Ft.	In.
Soil and weathered material	1	0
Limestone, light to dark bluish gray, hard, irregularly bedded, flint-like fracture, Cambridge	6	6
Bottom of quarry.		

The Cambridge limestone as described above was sampled by R. E. Lamborn on June 11, 1941, for chemical analysis.

Sample No. 344

Chemical analysis of Cambridge limestone from quarry on J. A. Dixon property, Section 24, Highland Township, Muskingum County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	44.72
Alumina, Al_2O_3	1.07
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.53
Iron disulphide, FeS_2	0.08
Magnesium oxide, MgO	0.33
Calcium oxide, CaO	28.72
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.09
Water, hydroscopic, H_2O-	0.45
Water, combined, H_2O+	0.30
Carbon dioxide, CO_2	23.24
Titanium dioxide, TiO_2	0.07
Phosphorus pentoxide, P_2O_5	0.09
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.19
Carbon, organic, C	0.04
Hydrogen, organic, H	----
Total	100.00

The per cent of each of the compounds present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.01
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.72
Silica, SiO_2	43.46
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	0.85
Iron disulphide, FeS_2	0.08
Titanium dioxide, TiO_2	0.07
Calcium phosphate, $3CaO.P_2O_5$	0.19
Calcium sulphate, $CaO.SO_3$	0.07
Calcium carbonate, $CaO.CO_2$	51.02
Magnesium carbonate, $MgO.CO_2$	0.69
Manganese carbonate, $MnO.CO_2$	0.31
Water, hydroscopic, H_2O-	0.45
Organic matter	0.04
Unbalanced components (deficiency CO_2, H_2O)	+0.02
Total	100.00

Bloomfield Limestone

The name Bloomfield was first applied by Stout to a thin limestone which closely underlies the Anderson coal and which is well developed near Bloomfield, Highland Township, Muskingum County. It is not a widely distributed member for the known outcrops in this county are confined to Monroe, Highland, Salem, Perry, Salt Creek, Bluerock, Harrison, and Brush Creek townships. Here it is a hard bluish gray, dense siliceous limestone having an average thickness of about 1 foot 5 inches and a maximum development of about 2 feet 6 inches. Its average position is about 5 feet below the Anderson coal. The exposures at the type locality about three-fourths of a mile west of Bloomfield in the southwest part of Section 9, Highland Township, are described as follows:

	Ft.	In.
Coal blossom, Anderson	1	0
Clay and covered	6	0
Limestone, bluish gray, dense, hard, tough, siliceous, somewhat laminated, Bloomfield	2	6
Shale and covered	13	6
Limestone, gray, nodular, fossiliferous, Cambridge	3	0

The Bloomfield limestone exposed at this place was sampled on October 8, 1943, by R. E. Lamborn for chemical analysis.

Sample No. 433

Chemical analysis of Bloomfield limestone from outcrop, Southwest Section 9, Highland Township, Muskingum County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	3.69
Alumina, Al_2O_3	0.50
Ferric oxide, Fe_2O_3	0.14
Ferrous oxide, FeO	0.56
Iron disulphide, FeS_2	0.26
Magnesium oxide, MgO	0.37
Calcium oxide, CaO	51.85
Sodium oxide, Na_2O	0.04
Potassium oxide, K_2O	0.06
Water, hydroscopic, H_2O-	0.06
Water, combined, H_2O+	0.49
Carbon dioxide, CO_2	41.14
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.02
Sulphur trioxide, SO_3	0.09
Manganous oxide, MnO	0.43
Total	99.71

The per cent of each of the mineral components in Sample No. 433 as determined by calculation (Lamborn) from the chemical analysis is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.00
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.28
Silica, SiO_2	3.10
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.16
Ferrous carbonate, $FeO.CO_2$	0.90
Iron disulphide, FeS_2	0.26

Titanium dioxide, TiO_2	0.01
Calcium phosphate, $3CaO.P_2O_5$	0.04
Calcium sulphate, $CaO.SO_3$	0.15
Calcium carbonate, $CaO.CO_2$	92.39
Magnesium carbonate, $MgO.CO_2$	0.77
Manganese carbonate, $MnO.CO_2$	0.70
Water, hydroscopic, H_2O-	0.06
Unbalanced components (excess CO_2, H_2O)	-0.11
Total	99.71

Portersville Member

The Portersville member has no economic importance for its limestone content as it is composed of dark fossiliferous shale with only thin nodular limestone distributed irregularly throughout the mass.

Ewing Limestone

The Ewing limestone in Muskingum County consists of scattered nodules of ferruginous limestone embedded in clays closely underlying the Barton coal. Such nodular deposits are best developed in Harrison and Bluerock townships but even here no economic importance can be attached to this member. For an analysis of the Ewing limestone see sections of this report dealing with the Ewing in Noble County.

Ames Limestone

The horizon of the Ames limestone occurs above drainage in parts of every township in Muskingum County lying east of a line extending from eastern Clay Township to eastern Salem Township. Across its field of outcrop in this county the Ames limestone is typical in its lithologic characteristics and remarkably persistent. The thickness of the stone varies from a few inches to a maximum of 5 feet but a thickness of 3 feet or more is rare. The limestone is probably the most uniform across Salt Creek and Union townships where the member measures close to 2 feet in thickness. According to Stout the average thickness of the Ames limestone on the outcrop in Muskingum County is 1 foot 7 inches. [1]

In 1917 the Ames limestone was sampled at an outcropping of the member along the road in Section 10, Union Township, about one-half mile south of New Concord where it has a thickness of 1 foot 8 inches. The sample was analyzed by D. J. Demorest. [2]

Sample No. 1009

Chemical analysis of Ames limestone from outcrop near New Concord, Section 10, Union Township, Muskingum County, D. J. Demorest, analyst

	Per cent
Silica, SiO_2	4.77
Alumina, Al_2O_3	1.83
Ferric oxide, Fe_2O_3	6.34
Calcium oxide, CaO	46.28

[1] *Stout, Wilber, op. cit., p. 255.*

[2] *Stout, Wilber, op. cit., pp. 257-258.*

Magnesium oxide, MgO	1.45
Sulphur, S	0.14
Phosphorus, P	0.18
Titanium dioxide, TiO_2	0.10

The mineral composition as calculated (Stout) from the chemical analysis is as follows:

	Per cent
Clay, $Al_2O_3.2SiO_2.2H_2O$	4.63
Silica, SiO_2	2.62
Iron disulphide, FeS_2	0.30
Ferrous carbonate, $FeO.CO_2$	7.64
Titanium dioxide, TiO_2	0.10
Calcium phosphate, $3CaO.P_2O_5$	0.90
Calcium carbonate, $CaO.CO_2$	81.77
Magnesium carbonate, $MgO.CO_2$	3.05
Total	101.01

Skelley Limestone

About 38 feet on an average above the Ames limestone in Muskingum County is the stratigraphic position of the Skelley, a thin discontinuous limestone rarely measuring 1 foot and averaging about 4 inches in thickness. The importance of this member lies chiefly in its stratigraphic interest.

Clarksburg Limestone

The Clarksburg limestone is probably represented in Muskingum County by occasional pockets of thin nodular impure limestone occurring about midway between the Ames limestone and Pittsburgh coal. At no place in Ohio is this limestone known to occur in good enough development to warrant much economic interest.

Summerfield Limestone

Outcrops of the Summerfield limestone have been recognized in Meigs, Bluerock, southeastern Salt Creek, Rich Hill, and Union townships. Where exposed the member consists of discontinuous layers of somewhat brecciated limestone interstratified with clay shale. The thickness varies from 3 feet to 15 feet with an average of about 6 feet. The Summerfield limestone was formerly quarried near the summit of the hill in the north central part of Section 4, Union Township. It has likewise been quarried on a small scale from the summit of the high hill on the Fisher property at the north edge of Section 22, Highland Township. Here the limestone measures about 4 feet in thickness and appears to be of good quality. Analyses of the Summerfield limestone are given in pages of this report dealing with this member in its best field of development in Guernsey and Noble counties.

Pittsburgh Limestone

The outcrops of the Pittsburgh limestone have essentially the same areal distribution as the Summerfield previously described. The limestone occurs from 10 to 20 feet below the Pittsburgh coal and averages approximately 10 feet in thickness in this county. It consists for the most part of several layers of impure, ferruginous, siliceous, argillaceous limestone separated by argillaceous shale. No samples of this limestone were collected from outcrops in Muskingum County.

Redstone Limestone

The horizon of the Redstone limestone occurring about 20 feet above the Pittsburgh coal is occupied over much of southeastern Muskingum County by sandstone and sandy shale. Limestone has been recognized in central Rich Hill Township, northwestern Meigs Township, and southeastern Bluerock Township. In these areas the limestone is thin and poorly developed.

Fishpot Limestone

The outcrops of the Fishpot limestone in Muskingum County are confined to the high hills and ridges in Bluerock, western Meigs, western Rich Hill, southern Union, and southeastern Salt Creek townships. It is found at somewhat lower levels on the hills in southeastern Rich Hill and eastern Meigs townships. The thickness of this member varies from 1 foot to about 22 feet but the average is about 10 feet. The Fishpot limestone is best developed in Meigs Township. Concerning the value of this limestone in Muskingum County, where it was formerly known as the Sewickley limestone, Stout writes as follows. [1]

"Like most of the fresh-water limestones in the lower part of the Monongahela and the upper parts of the Conemaugh formation the Sewickley is a light gray, rather hard but brittle, noncrystalline limestone of fair purity. The rock is everywhere siliceous in character and in places along the outcrop where weathering agencies are active it is so impregnated with iron oxide that it has a buff or reddish color. It is doubtful whether it is sufficiently pure to slake readily when calcined. The main use of the Sewickley limestone in Muskingum County is evidently for road building."

The Fishpot limestone has been quarried for a number of years on the Burlingham property in the south central part of Section 2, Meigs Township. The product of the quarry has been utilized chiefly for road construction although small quantities have been marketed for agricultural use. The beds exposed at this locality are described below.

		Ft.	In.
Shale, dark bluish gray		3	0
Coal, shaly, and black shale	Meigs Creek or No. 9	1	9
Shale parting	Meigs Creek or No. 9	--	1
Coal	Meigs Creek or No. 9	--	11
Shale parting	Meigs Creek or No. 9	--	1
Coal	Meigs Creek or No. 9	1	9
Covered interval		9	0
Limestone, light gray to buff, dense texture, one layer, sampled	Fishpot	--	9
Shale, bluish gray, calcareous, not sampled	Fishpot	--	5
Limestone, gray to buff, dense texture, one layer, sampled	Fishpot	1	2

[1] *Stout, Wilber, op. cit., p. 272.*

Shale, calcareous, not sampled	Fishpot (cont.)	....	--	2
Limestone, light brown to buff, one layer, sampled		....	3	4
Shale, brown to bluish, calcareous, not sampled		....	--	10
Limestone, brown, impure, not sampled		....	--	8
Shale, brown to bluish, calcareous, not sampled		....	--	5
Limestone, brown, argillaceous, not sampled		....	--	6
Shale, brown to dark bluish gray, not sampled		....	--	6
Limestone, light brown, dense, one layer, not sampled		....	2	0
Bottom of quarry.				

The upper 5 feet 3 inches of the Fishpot limestone exposed in this quarry was sampled by R. E. Lamborn on July 2, 1941, for chemical analysis.

Sample No. 359

Chemical analysis of Fishpot limestone from quarry on Burlingham property, Section 2, Meigs Township, Muskingum County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	5.88
Alumina, Al_2O_3	1.40
Ferric oxide, Fe_2O_3	0.04
Ferrous oxide, FeO	0.74
Iron disulphide, FeS_2	0.10
Magnesium oxide, MgO	4.07
Calcium oxide, CaO	45.75
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.07
Water, hydroscopic, H_2O-	0.45
Water, combined, H_2O+	0.38
Carbon dioxide, CO_2	40.80
Titanium dioxide, TiO_2	0.06
Phosphorus pentoxide, P_2O_5	0.05
Sulphur trioxide, SO_3	0.07
Manganous oxide, MnO	0.14
Carbon, organic, C	0.04

Hydrogen, organic, H	----
Total	100.06

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.84
Silicates $Al_2O_3.2SiO_2.2H_2O$	2.72
Silica, SiO_2	4.23
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	1.19
Iron disulphide, FeS_2	0.10
Titanium dioxide, TiO_2	0.06
Calcium phosphate, $3CaO.P_2O_5$	0.11
Calcium sulphate, $CaO.SO_3$	0.12
Calcium carbonate, $CaO.CO_2$	81.46
Magnesium carbonate, $MgO.CO_2$	8.51
Manganese carbonate, $MnO.CO_2$	0.23
Water, hydroscopic, H_2O-	0.45
Organic matter	0.04
Unbalanced components (excess CO_2, H_2O)	-0.04
Total	100.06

Benwood Limestone

The Benwood limestone is of slight importance in Muskingum County as the beds are generally thin, discontinuous, and widely spaced in calcareous shales, and as the member is confined in its distribution to Meigs and central Rich Hill townships. The base of the limestone lies close above the Meigs Creek coal. The member varies from 30 to 70 feet in thickness most of which is calcareous shale. The limestone is generally gray to bluish gray in color and arenaceous in composition.

Uniontown Limestone

Outcrops of the Uniontown limestone are confined in their distribution to the high ridges in Meigs Township and southeastern Bluerock Township. It consists of thin limestone interstratified with calcareous shale having an average thickness of about 10 feet and lying close below the Uniontown coal. Like the Benwood it tends to be arenaceous in composition.

Elm Grove Limestone

The Elm Grove limestone which lies close above the Waynesburg or No. 11 coal is confined in its outcrops to High Hill in Meigs Township where it measures less than 1 foot in thickness. For an analysis of the limestone see section of this report dealing with the Elm Grove limestone in Belmont County.

NOBLE COUNTY

General Considerations

The bedrocks exposed at the surface in Noble County, which embraces an area of about 405 square miles, belong to the Conemaugh and Monongahela series of the Pennsylvanian system and to the Washington series of the Permian system. The total thickness of the beds exposed across this area is approximately 750 feet. Owing to the regional dip of the strata in a southeastern direction, the oldest beds reach the surface in the northwestern part and younger and overlying members in the series outcrop progressively to the southeast. The pattern of outcrop, however, is by no means uniform or regular due to the strong expression of well-defined structures. The axis of the Parkersburg-Lorain syncline, the largest structural trough in the eastern half of Ohio, passes just west of the serrated southwestern border of Noble County. Here strata of Monongahela and Permian ages are exposed at the surface. From the axis of the Parkersburg-Lorain syncline the beds rise to the northeast across southwestern Noble County at a rate of 35 to 50 feet per mile for a distance of 4 to 9 miles before again assuming the regional southeastern direction of maximum dip. The broad structural arch is thus formed extending in a northwest-southeast direction across Noble County. The valley of Duck Creek corresponds very closely in position with the high western rim of this structural arch. Along this valley the belt of Conemaugh outcrops extends far to the southeast entirely across Noble County in northern Washington County. In the high hills and ridges both to the east and west of Duck Creek in southwestern and southeastern Noble County the Conemaugh is overlain by strata of Monongahela age which in turn is capped by sandstones and shales of the Permian system. A generalized section of the strata exposed in Noble County derived in part from Condit [1] and in part from unpublished notes by Wilber Stout and George White is as follows:

Generalized Section of Bedrocks Outcropping in Noble County

	Ft.	In.
Permian system		
Washington series		
Shale and sandstone, not subdivided	125	0
Coal, shaly, and carbonaceous shale, Waynesburg A	1	7
Shale, soft, calcareous	5	0
Limestone, with beds of calcareous shale, locally developed, Mt. Morris	2	5
Shale, with local deposits of sandstone, Waynesburg sandstone horizon	35	0
Limestone, dark, in one ledge or two or more ledges separated by thin shale beds, Elm Grove	1	6
Shale, dark	8	0
Pennsylvanian system		
Monongahela series		
Coal, shaly, and carbonaceous shale, locally present, Waynesburg or No. 11	-	10
Clay shale, calcareous	1	0
Shale and sandstone, Gilboy sandstone horizon	11	5
Coal, shaly and carbonaceous shale, local, Little Waynesburg	-	4
Shale, soft, calcareous	5	3
Limestone and calcareous shale, local in occurrence, Waynesburg	2	6
Shale, sandy, with bodies of sandstone in some areas, Uniontown sandstone horizon	30	7

[1] *Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17, p. 157, 1912.*

Coal, shaly, and carbonaceous shale, Uniontown or No. 10	1	8
Shale, soft, calcareous	3	9
Limestone, gray to dark, with calcareous shale interstratified, Uniontown	7	6
Shale, sandy, and thin sandstone, not persistent	20	0
Limestone, gray to dark, dense, with calcareous shale, Benwood	48	6
Shale, gray, sandy grading to sandstone in east part of county, Sewickley	20	0
Shale, gray to dark	9	0
Coal, with several shale partings, persistent, Meigs Creek or No. 9	5	3
Shale, gray to light, argillaceous to sandy	9	6
Sandstone, persistent, Fishpot	8	0
Shale, sandy	7	10
Coal and carbonaceous shale, Fishpot	1	5
Shale, gray to pink, generally argillaceous and calcareous	3	0
Limestone, gray to dark, dense, in layers separated by calcareous shale partings, persistent, Fishpot	20	0
Shale	10	8
Coal and carbonaceous shale, locally present, Pomeroy or No. 8a	-	4
Limestone, light to dark gray, dense, and calcareous shale, locally developed, Redstone	5	0
Shale, sandy, grading to sandstone, Pittsburgh sandstone horizon	14	3
Shale, dark	6	9
Coal, generally thin and with carbonaceous shale, Pittsburgh or No. 8	-	8
Conemaugh series		
Clay, interlain with several beds of dark gray limestone	22	0
Shale, with beds of sandstone and red clay	30	0
Limestone, gray and buff, in several beds interlain with clay, Summerfield	6	0
Clay shale, reddish, with a few beds of sandstone	27	0
Clay, red, with concretionary limestone and hematite	17	0
Shale, sandy, with layers of sandstone	35	0
Shale, with one or more layers of impure fossiliferous limestone, Skelley horizon	23	0
Shale, sandy, with irregular concretionary beds of impure non-fossiliferous limestone	18	0
Limestone, gray, fossiliferous. In some localities it is a dark, shaly, impure limestone in several beds interlain with shale, Ames	2	0

Shale, sandy	9	0
Coal wanting in some localities, Harlem	1	0
Shale varying to cross-bedded sandstone	26	0
Limestone, in layers or nodules interlain with clay. Replaced locally by sandstone, Ewing	6	0
Clay shale, generally red	10	0
Shale, increasingly sandy in lower portion	36	0
Shale, dark, fossiliferous, Portersville horizon	3	0
Coal, Anderson	1	6
Clay shale	11	0
Limestone, nodular to massive, fossiliferous, Cambridge	2	0
Shale, sandy	20	0
Sandstone, shaly, Buffalo	18	0
Shale, dark, fossiliferous, Brush Creek	3	0

Outcrops of the Conemaugh series in Noble County are not especially rich in good deposits of high-grade limestone. Many of its limestone members are thin and rather discontinuous, having importance only for their stratigraphic relationship. Of the Cambridge, Ewing, Ames, Skelley, Summerfield, and Pittsburgh members represented in outcrops, the Summerfield ranks first in purity, thickness of deposit, and utilization. Its importance is somewhat overshadowed, however, by the Fishpot and Benwood-Uniontown members of the Monongahela series, which are widely employed at many small quarries in the southeastern half of the county for road stone and for agricultural limestone. Limestones of any economic importance are not known to occur in the Permian strata in this county.

The Pennsylvanian beds below drainage in Noble County includes the Pottsville and Allegheny series and the lower part of the Conemaugh having an aggregate thickness of 500 to 550 feet. A few thin limestones, 10 feet or less in thickness, may occur in this series. From the records of wells drilled for oil and gas in Noble County it is known that the Maxville limestone, occurring at the base of the Pennsylvanian, is present in varying thickness over a few small scattered areas in the eastern half of Noble County. These areas occur in Elk, Jackson, Stock, Marion, Seneca, Wayne, and Beaver townships. Here the thickness of the limestone is generally less than 100 feet and the depth varies from 700 to about 1,200 feet.

Below the Maxville limestone, shale with thin sandstone prevails to the top of the Big Lime which is reached in Noble County at depths below sea level ranging from 2,500 feet in northwestern Brookfield Township to 4,000 feet in southeastern Elk Township.

Cambridge Limestone

In Noble County the Cambridge limestone is confined in its distribution to the valley of Buffalo Creek in the northern part of Buffalo Township and to the valley of the West Fork of Duck Creek northwest of Belle Valley in Noble Township. As the Cambridge limestone is generally thin in this area, its possibilities for economic use are trifling.

Ewing Limestone

The Ewing limestone occurring approximately midway in vertical section between the Cambridge limestone below and Ames limestone above is confined in distribution in Noble County to the northwestern part. Outcrops occur above drainage along the West Fork of Duck Creek northwest of Caldwell and along the valley of Buffalo Creek in Buffalo and northwestern Center townships. Locally the horizon of the Ewing limestone is occupied by sandstone. The limestone is probably best known along the valley of Duck Creek northwest of Caldwell where it may consist of several beds of gray limestone interlain with shale having a total thickness of as much as 10 feet. [1] It is well exposed along the Caldwell - Belle Valley road near the old abandoned shaft mine of the Cambridge Collieries Company in the southwest quarter of Section 28, Noble County. The Barton coal is wanting at this locality but the Ewing is well expressed as indicated in the following section.

		Ft.	In.
Shale, yellowish to reddish brown, sandy		10	0
Limestone, gray to light brownish gray, dense, hard	Ewing	1	1
Clay shale, greenish gray	Ewing	-	1
Limestone, gray to brownish gray	Ewing	-	8
Clay shale, bluish gray to light greenish gray		4	0

The two beds of limestone having a total thickness of 1 foot 9 inches were sampled on October 6, 1943, by R. E. Lamborn for chemical analysis.

Sample No. 431

Analysis of Ewing limestone from outcrop along road, southwest quarter of Section 28, Noble Township, Noble County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	2.68
Alumina, Al_2O_3	1.00
Ferric oxide, Fe_2O_3	0.26
Ferrous oxide, FeO	0.40
Iron disulphide, FeS_2	0.07
Magnesium oxide, MgO	0.39
Calcium oxide, CaO	52.50
Sodium oxide, Na_2O	0.01
Potassium oxide, K_2O	0.11
Water, hydroscopic, H_2O-	0.14
Water combined, H_2O+	0.48
Carbon dioxide, CO_2	41.56
Titanium dioxide, TiO_2	0.03
Phosphorus pentoxide, P_2O_5	0.08
Sulphur trioxide, SO_3	0.02
Manganous oxide, MnO	0.33
Total	100.06

The per cent of each of the various mineral components in Sample No. 431 as determined by calculation (Lamborn) from the chemical analysis is given below.

[1] *Condit, D. D., op. cit. p. 161.*

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.05
$Al_2O_3.2SiO_2.2H_2O$	1.50
Silica, SiO_2	1.50
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.30
Ferrous carbonate, $FeO.CO_2$	0.65
Iron disulphide, FeS_2	0.07
Titanium dioxide, TiO_2	0.03
Calcium phosphate, $3CaO.P_2O_5$	0.17
Calcium sulphate, $CaO.SO_3$	0.04
Calcium carbonate, $CaO.CO_2$	93.51
Magnesium carbonate, $MgO.CO_2$	0.82
Manganese carbonate, $MnO.CO_2$	0.53
Water, hydroscopic, H_2O-	0.14
Unbalanced components (excess CO_2, H_2O)	-0.25
Total	100.06

Ames Limestone

Outcrops of the Ames limestone in Noble County are confined for the most part to the northwestern part of the county east and northeast of Brookfield Township. Along the valley of Duck Creek this limestone is above drainage in Noble Township and in Olive Township as far southeast as South Olive. It likewise outcrops along the larger valleys northwest of a line extending from Sarahsville to the northeast corner of Wayne Township including Buffalo, northern Center, western Seneca, and western Wayne townships. In typical development the Ames is a gray to greenish gray semi-crystalline fossiliferous limestone a foot or two in thickness. According to Condit [1] it becomes quite shaly and impure in the southeastern part of its belt of outcrops in Noble County.

The Ames is not known to have been employed to any extent in Noble County as a source for limestone.

Skelley Limestone

The Skelley as a possible source for limestone is unimportant in Noble County. The member is represented in scattered outcrops by a few inches of impure ferruginous limestone occurring from 30 to 35 feet above the Ames limestone previously described.

Summerfield Limestone

The Summerfield limestone occurring about 120 feet above the Ames limestone and about 55 feet below the top of the Conemaugh series in Noble County was so named because of its occurrence on outcrops west of Summerfield in Marion Township. [2] The horizon of this member outcrops widely in Noble County as it is present in every township with the exception of Sharon in the southwestern part. So far as now known it is best developed in Noble County over a belt extending from Caldwell northeast to Salesville and Quaker City including parts of Beaver, Wayne, Seneca, Marion, Center, and northern Stock townships. Here the altitude varies in the south from 975 feet near Duval, Center Township, to 900 feet at East Union, Stock Township. The bed rises to the northeast reaching altitudes of about 1,020 feet in northeastern Wayne and northwestern Beaver townships. The limestone is

[1] *Condit, D. D., op. cit. pp. 158-163.*

[2] *Condit, D. D., op. cit., p. 160*

generally gray to buff in color consisting in general of one or more layers separated by their shale partings. The thickness of the limestone varies from a few inches to a probable maximum of 6 to 8 feet. Where best developed it is dense, hard, and of good purity. Fracture surfaces of the limestone often show the presence of minute veinlets of calcite. The limestone has been quarried at one or two localities in Noble County but its local importance is somewhat overshadowed by the thicker and more important Fishpot limestone which occurs 120 feet higher in the series.

The Summerfield limestone was formerly quarried on the J. K. Shamhart property about 2 miles northwest of Batesville. The quarry is located near the bottom of a small ravine just north of the east-west road in the northeast quarter of Section 28, Beaver Township. Here the limestone is crushed to the necessary size and utilized for road construction. When visited in 1941, 6 feet 7 inches of strata belonging to the Summerfield was exposed as described in the following section.

		Ft.	In.
Shale, weathered		4	0
Limestone, light bluish gray, dense-textured, a few veinlets of calcite, sampled	Summerfield	1	0
Shale, light bluish gray, calcareous, not sampled	Summerfield	-	6
Limestone, light bluish to brownish gray, dense texture, hard and tough, sampled	Summerfield	1	6
Shale, calcareous, not sampled	Summerfield	-	1
Limestone, light bluish to brownish gray, dense texture, hard and tough, sampled	Summerfield	2	0
Shale, light bluish gray, calcareous, with lenses of impure limestone, not sampled	Summerfield	-	6
Limestone, light bluish to brownish gray, dense texture, tough, sampled	Summerfield	1	0
Bottom of exposure.			

The limestone beds described above having a total thickness of 5 feet 6 inches were sampled on August 13, 1941, by R. E. Lamborn for chemical analysis.

Sample No. 372

Analysis of Summerfield limestone from quarry on J. K. Shamhart property, Section 28, Beaver Township, Noble County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	4.82
Alumina, Al_2O_3	0.66
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	0.86
Iron disulphide, FeS_2	0.06
Magnesium oxide, MgO	3.50
Calcium oxide, CaO	47.44
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.08
Water, hydroscopic, H_2O-	0.16
Water, combined, H_2O+	0.20
Carbon dioxide, CO_2	41.68
Titanium dioxide, TiO_2	0.07
Phosphorus pentoxide, P_2O_5	0.05
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.28
Carbon, organic, C	0.07
Hydrogen, organic, H	--
Total	100.02

The per cent of each of the mineral compounds probably present in the sample as calculated (Lamborn) from the chemical analysis is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.92
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.76
Silica, SiO_2	4.04
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.03
Ferrous carbonate, $FeO.CO_2$	1.39
Iron disulphide, FeS_2	0.06
Titanium dioxide, TiO_2	0.07
Calcium phosphate, $3CaO.P_2O_5$	0.11
Calcium sulphate, $CaO.SO_3$	0.07
Calcium carbonate, $CaO.CO_2$	84.52
Magnesium carbonate, $MgO.CO_2$	7.32
Manganese carbonate, $MnO.CO_2$	0.45
Water, hydroscopic, H_2O-	0.16
Organic matter	0.07
Unbalanced components (deficiency CO_2, H_2O)	+0.05
Total	100.02

The Summerfield is probably the most important limestone outcropping in Center, Seneca, and western Marion townships where, including the thin interstratified shale, it varies in thickness from about 2 to 4 feet. It is exposed at a few localities along the site of the old abandoned railroad southeast of Sarahsville and around the headwaters of Duck Creek in southeastern Center, northwestern Stock, and southwestern Marion townships. The following measurements were secured along a small ravine, one-eighth mile north of the road in the north central part of Section 29, Center Township.

	Ft.	In.
Shale, sandy	15	0

Limestone, gray to light brownish gray, generally dense texture, with minute veinlets of calcite, Summerfield	2	4
Clay shale, calcareous, with many nodules of limestone	1	6

The 2-foot 4-inch bed of Summerfield limestone was sampled at this locality by R. E. Lamborn, on October 1, 1941, for chemical analysis.

Sample No. 430

Analysis of Summerfield limestone from outcrop, north central Section 29, Center Township, Noble County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	1.44
Alumina, Al_2O_3	0.47
Ferric oxide, Fe_2O_3	0.00
Ferrous oxide, FeO	0.32
Iron disulphide, FeS_2	0.13
Magnesium oxide, MgO	0.55
Calcium oxide, CaO	53.74
Sodium oxide, Na_2O	0.04
Potassium oxide, K_2O	0.04
Water, hydroscopic, H_2O-	0.08
Water, combined, H_2O+	0.35
Carbon dioxide, CO_2	42.60
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.02
Sulphur trioxide, SO_3	0.03
Manganous oxide, MnO	0.17
Total	99.99

The per cent of each of the mineral components present in Sample No. 430 as determined by calculation from chemical analysis (Lamborn), is given below:

	Per cent
Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.83
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.36
Silica, SiO_2	0.89
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.00
Ferrous carbonate, $FeO.CO_2$	0.52
Iron disulphide, FeS_2	0.13
Titanium dioxide, TiO_2	0.01
Calcium phosphate, $3CaO.P_2O_5$	0.04
Calcium sulphate, $CaO.SO_3$	0.05
Calcium carbonate, $CaO.CO_2$	95.84
Magnesium carbonate, $MgO.CO_2$	1.15
Manganese carbonate, $MnO.CO_2$	0.27
Water, hydroscopic, H_2O-	0.08
Unbalanced components (excess CO_2, H_2O)	-0.18
Total	99.99

Pittsburgh Limestone

The Pittsburgh limestone in Noble County occurs from 20 to 40 feet above the Summerfield limestone and about 90 feet on an average below the Meigs Creek or No. 9 coal. It closely underlies the horizon of the Pittsburgh coal, but in this area the coal is thin or wanting. The horizon of the limestone is widely distributed as outcrops occur in every township. The limestone is generally a bluish gray stone which rarely exceeds 2 feet in thickness and in some areas is wanting. Limestones of this type can furnish a ready supply for the building and surfacing of roads.

Redstone Limestone

The Redstone limestone, which lies close below the Redstone or No. 8a coal in the upper part of the 25-foot interval separating the Pittsburgh and Redstone coals, is not well developed on the outcrop in Noble County. Here the Pomeroy coal is poorly expressed and thin sandstone and sandy shale are prominently developed in the Pittsburgh-Pomeroy coal interval.

Fishpot Limestone

The Fishpot limestone is a persistent member on the outcrop in Noble County where it has been widely used as a quarry stone. The stratigraphic position of this limestone is close below the thin Fishpot coal and from 20 to 30 feet below the widely distributed Meigs Creek or No. 9 coal. The thickness of the limestone member ranges from 1 or 2 feet where poorly developed to a maximum of 25 to 30 feet. In comparison with other limestone members of the Monongahela series, the Fishpot tends to be more regularly bedded with a lower per cent of shale occurring as partings. In the upper part of the Fishpot, the part most widely used as a quarry stone, the limestone layers range in thickness from a few inches to a maximum of 4 or 5 feet, whereas the shale partings vary from an inch or so to 1 foot in thickness. The limestone is variously colored gray, bluish gray, and light chocolate brown. It is generally dense in texture and has a dull earthy appearance. On fracturing the stone breaks into fragments which have smooth rounded surfaces and sharp edges resembling pieces of flint or chert in general contour. In distribution the outcrops of the Fishpot limestone in Noble County are divided into two areas by the valley of Duck Creek. The southwestern area includes Brookfield, southwestern Noble, northeastern Sharon, southwestern Olive, and eastern Jackson townships, whereas the eastern area embraces parts of Jefferson, Enoch, Stock, Center, Marion, and Beaver townships. The limestone has been worked in a number of small quarries along the outcrop and has been utilized locally for road construction and repair and for agricultural limestone.

The Fishpot limestone member yields stone for road construction in a quarry operated by David Betch and located on the William Egan property near Truckyho School in the east central part of Section 11, Beaver Township. The total thickness of the limestone and interstratified shale approximates 12 feet. A description of the exposures in the pit as well as overlying beds outcropping on the hillside is given below:

		Ft.	In.
Track level, abandoned mine, Meigs Creek or No. 9 coal		---	---
Covered interval		16	2
Shale, gray		10	0
Shale, dark, carbonaceous		-	6
Shale, soft		-	2
Coal, impure	Fishpot	-	7
Shale, dark gray	Fishpot	-	8
Coal	Fishpot	1	1
Shale, gray	Fishpot	-	3
Coal, impure	Fishpot	-	7

			Feet	Inches
Shale, calcareous			-	8
Limestone, bluish gray, tough, one layer, sampled	Fishpot		2	4
Shale, calcareous, with a thin streak of impure limestone, not sampled			-	6
Limestone, bluish to brownish gray, somewhat brittle, one layer, sampled			2	0
Shale, calcareous, not sampled			-	2 1/2
Limestone, bluish to brownish gray, dense-textured, brittle, one layer, sampled			1	0
Shale, bluish to brownish gray, calcareous, not sampled			-	1
Limestone, bluish to brownish gray, dense texture, sampled			2	8
Shale, bluish gray, calcareous, not sampled			-	6
Limestone, bluish to brownish gray, dense-textured, one layer, sampled			2	6

Bottom of quarry. Altitude 1,112 feet.

The limestone exposed in this quarry as described above was sampled by R. E. Lamborn for chemical analysis on August 14, 1941.

Sample No. 373

Chemical analysis of Fishpot limestone from quarry on William Egan property, Section 11, Beaver Township, Noble County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	10.02
Alumina, Al_2O_3	3.03
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	0.88
Iron disulphide, FeS_2	0.44
Magnesium oxide, MgO	5.60
Calcium oxide, CaO	39.80
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.07
Potassium oxide, K_2O	0.40
Water, hydroscopic, H_2O-	0.50
Water, combined, H_2O+	0.95
Carbon dioxide, CO_2	37.84
Titanium dioxide, TiO_2	0.14
Phosphorus pentoxide, P_2O_5	0.08
Sulphur trioxide, SO_3	0.05
Manganous oxide, MnO	0.16

Carbon, organic, C	0.05
Hydrogen, organic, H	---
Total	100.04

The per cent of each of the compounds probably present in Sample No. 373 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2 2H_2O$	4.25
Silicates $Al_2O_3.2SiO_2.2H_2O$	3.51
Silica, SiO_2	6.45
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.03
Ferrous carbonate, $FeO.CO_2$	1.42
Iron disulphide, FeS_2	0.44
Titanium dioxide, TiO_2	0.14
Calcium phosphate, $3CaO.P_2O_5$	0.17
Calcium sulphate, $CaO.SO_3$	0.08
Calcium carbonate, $CaO.CO_2$	70.82
Magnesium carbonate, $MgO.CO_2$	11.70
Manganese carbonate, $MnO.CO_2$	0.26
Water, hydroscopic, H_2O-	0.50
Organic matter	0.05
Unbalanced components (deficiency CO_2, H_2O)	+0.22
Total	100.04

Mr. Charles Garrett operates a quarry in the Fishpot limestone on the Mila Carpenter property in the southeast quarter of Section 1, Beaver Township. The limestone is quarried by hand labor after which it is either crushed for road construction or pulverized for agricultural purposes. The rock succession and character of the beds exposed at this locality are described below:

	Ft.	In.
Coal and black shale, weathered Fishpot coal horizon	1	2
Shale, weathered	1	4
Limestone, bluish gray, dense-textured, one layer, sampled	2	8
Shale, bluish gray, calcareous, not sampled	-	5
Limestone, bluish gray, dense, flint-like fracture, one layer, sampled	3	0
Shale, calcareous, not sampled	-	2
Limestone, bluish gray, dense texture, one layer, sampled	3	0
Shale, bluish gray, calcareous, not sampled	-	7
Limestone, bluish gray, dense texture, flint-like fracture, one layer, sampled	1	8
Bottom of quarry. Altitude about 1,040 feet.		

The four limestone layers occurring in this series and having an aggregate thickness of 10 feet 4 inches were sampled by R. E. Lamborn for chemical analysis on August 7, 1941.

Sample No. 367

Chemical analysis of Fishpot limestone from quarry on Mila Carpenter property, Section 1, Beaver Township, Noble County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	9.61
Alumina, Al_2O_3	1.55
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.95
Iron disulphide, FeS_2	0.15
Magnesium oxide, MgO	5.83
Calcium oxide, CaO	40.92
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.08
Potassium oxide, K_2O	0.34
Water, hydroscopic, H_2O-	0.71
Water, combined, H_2O+	0.29
Carbon dioxide, CO_2	38.95
Titanium oxide, TiO_2	0.12
Phosphorus pentoxide, P_2O_5	0.14
Sulphur trioxide, SO_3	0.05
Manganous oxide, MnO	0.14
Carbon, organic, C	0.15
Hydrogen, organic, H	0.02
Total	100.02

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	3.86
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.13
Silica, SiO_2	7.78
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.53
Iron disulphide, FeS_2	0.15
Titanium dioxide, TiO_2	0.12
Calcium phosphate, $3CaO.P_2O_5$	0.31
Calcium sulphate, $CaO.SO_3$	0.08
Calcium carbonate, $CaO.CO_2$	72.68
Magnesium carbonate, $MgO.CO_2$	12.18
Manganese carbonate, $MnO.CO_2$	0.23
Water, hydroscopic, H_2O-	0.71
Organic matter	0.17
Unbalanced components (deficiency CO_2, H_2O)	+0.07
Total	100.02

A quarry in the Fishpot limestone operated by Osborn and Dimmerling is located in the southeast quarter of Section 29, Stock Township, on land owned by Richard Colland of Summerfield, Ohio. The member here consists of thick layers of dense compact limestone separated by thin shale partings. The overlying shale and impure coal are removed by stripping. The exposures at this locality are described as follows:

		Ft.	In.
Shale and covered		8	0
Coal, weathered	Fishpot	1	0
Shale parting	Fishpot	-	4
Coal, weathered	Fishpot	-	7
Shale, gray		-	6
Shale, bluish gray, calcareous		1	4
Limestone, light bluish to brownish gray, one layer, sampled	Fishpot	1	0

			Ft.	In.
Limestone, bluish to brownish gray, lower part mottled, one layer, sampled........	Fishpot (cont.)	....	2	6
Shale, bluish gray, calcareous, tough, not sampled		....	-	4
Limestone, bluish to brownish gray, dense texture, flint-like fracture; one layer, sampled		....	2	8
Shale, bluish gray, calcareous, not sampled		....	-	6
Limestone, light brown, dense texture, flint-like fracture, one layer, sampled		....	1	4
Shale, calcareous, not sampled...........		....	-	1
Limestone, light bluish gray, dense texture, flint-like fracture, one layer, sampled		....	3	6
Bottom of quarry.				

The limestone ledges quarried at this locality have an aggregate thickness of 11 feet. The stone is drilled with a pneumatic drill and loosened by blasting. Pulverized limestone for agricultural use is the chief product of the quarry. A sample of the limestone was cut from the quarry face by R. E. Lamborn on August 12, 1941, and was submitted for analysis.

Sample No. 370

Chemical analysis of Fishpot limestone from quarry operated by Osborn and Dimmerling, Section 29, Stock Township, Noble County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	10.47
Alumina, Al_2O_3	2.44
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	1.08
Iron disulphide, FeS_2	0.06
Magnesium oxide, MgO	5.45
Calcium oxide, CaO	40.18
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.06
Potassium oxide, K_2O	0.30
Water, hydroscopic, H_2O-	0.54
Water, combined, H_2O+	0.77
Carbon dioxide, CO_2	38.14
Titanium dioxide, TiO_2	0.13
Phosphorus pentoxide, P_2O_5	0.08
Sulphur trioxide, SO_3	0.02
Manganese oxide, MnO	0.19

Carbon, organic, C	0.06
Hydrogen, organic, H	--
Total	100.00

The per cent of the various compounds probably present in Sample No. 370 has been computed (Lamborn) from the chemical analysis.

Silicates	$(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	3.28
	$Al_2O_3.2SiO_2.2H_2O$	2.96
Silica, SiO_2		7.60
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$		0.03
Ferrous carbonate, $FeO.CO_2$		1.74
Iron disulphide, FeS_2		0.06
Titanium dioxide, TiO_2		0.13
Calcium phosphate, $3CaO.P_2O_5$		0.17
Calcium sulphate, $CaO.SO_3$		0.03
Calcium carbonate, $CaO.CO_2$		71.52
Magnesium carbonate, $MgO.CO_2$		11.39
Manganese carbonate, $MnO.CO_2$		0.31
Water, hydroscopic, H_2O-		0.54
Organic matter		0.06
Unbalanced components (deficiency CO_2, H_2O)		+0.18
Total		100.00

The Fishpot limestone has been worked in a small way in a quarry owned and operated by Charles R. Hamilton and located in the northwest quarter of Section 15, Brookfield Township. Here the limestone occurs near creek level along a small tributary to the West Fork of Duck Creek at an altitude of approximately 960 feet. The stone is crushed and screened to the various sizes necessary for road construction and repair. The character of the Fishpot member is given in the following description of exposures in the quarry.

		Ft.	In.
Shale, bluish gray		-	10
Limestone, light to dark bluish gray, somewhat mottled, one layer, sampled	Fishpot	-	9
Shale, calcareous, not sampled	Fishpot	-	4
Limestone, bluish gray, dense texture, one layer, sampled	Fishpot	-	8
Limestone, bluish gray, dense texture, one layer, sampled	Fishpot	3	10
Shale, dark, calcareous, not sampled	Fishpot	-	6
Shale, dark, highly calcareous, not sampled	Fishpot	-	7
Limestone, dark bluish gray, one bed, not sampled	Fishpot	2	0

Bottom of quarry.

The limestone ledges occurring above the 2-foot shale zone near the bottom of the quarry were sampled by R. E. Lamborn for chemical analysis on July 2, 1941.

Sample No. 358

Chemical analysis of Fishpot limestone from quarry of Charles Hamilton, Section 15, Brookfield Township, Noble County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	7.65
Alumina, Al_2O_3	1.42
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	0.88
Iron disulphide, FeS_2	0.40
Magnesium oxide, MgO	5.29
Calcium oxide, CaO	42.60
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.07
Potassium oxide, K_2O	0.28
Water, hydroscopic, H_2O-	0.80
Water, combined, H_2O+	0.42
Carbon dioxide, CO_2	39.75
Titanium dioxide, TiO_2	0.09
Phosphorus pentoxide, P_2O_5	0.05
Sulphur trioxide, SO_3	0.07
Manganous oxide, MnO	0.18
Carbon, organic, C	0.06
Hydrogen, organic, H	--
Total	100.04

The per cent of each of the various compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	3.23
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.42
Silica, SiO_2	5.98
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.03
Ferrous carbonate, $FeO.CO_2$	1.42
Iron disulphide, FeS_2	0.40
Titanium dioxide, TiO_2	0.09
Calcium phosphate, $3CaO.P_2O_5$	0.11
Calcium sulphate, $CaO.SO_3$	0.12
Calcium carbonate, $CaO.CO_2$	75.84
Magnesium carbonate, $MgO.CO_2$	11.05
Manganese carbonate, $MnO.CO_2$	0.29
Water, hydroscopic, H_2O-	0.80
Organic matter	0.06
Unbalanced components (deficiency CO_2, H_2O)	+0.20
Total	100.04

Mr. Lawrence King of Caldwell, Ohio, operates a quarry in the Fishpot limestone on the Oscar King property in the south central part of Section 21, Olive Township, Noble County. The quarry is located near stream level at an altitude of approximately 940. A section of the rocks exposed is given below.

	Ft.	In.
Shale, greenish gray to yellowish brown	12	0

		Feet	Inches
Shale, dark, carbonaceous, Fishpot coal horizon		-	1
Shale, greenish gray, calcareous		1	4
Limestone, brownish gray, dense texture, brittle, sampled	Fishpot	1	3
Limestone, light and dark bluish gray, mottled, sampled	Fishpot	1	3
Shale, dark bluish gray, highly calcareous, not sampled	Fishpot	-	6
Limestone, light bluish to brownish gray, mottled, one bed, sampled	Fishpot	2	0
Shale, calcareous, not sampled	Fishpot	-	2
Limestone, bluish gray, dense texture, brittle, sampled	Fishpot	2	0
Limestone, bluish gray, arenaceous, not sampled	Fishpot	-	8
Shale, bluish gray, calcareous, not sampled	Fishpot	1	5
Limestone, bluish gray, dense texture, argillaceous, becoming more impure downward, sampled	Fishpot	3	6
Bottom of quarry.			

Limestone from the entire face of the quarry is crushed for road stone, but only that part above the 8-inch arenaceous layer is pulverized for agricultural use. Two samples were cut from exposures in this quarry by R. E. Lamborn on June 12, 1942. Sample No. 380 was from the 3-foot 6-inch bed at the bottom of the exposure, whereas Sample No. 381 included the limestone above the 8-inch arenaceous bed.

Samples No. 380, 381

Chemical analyses of samples of Fishpot limestone from quarry on Oscar King property, Section 12, Olive Township, Noble County, Nalin Laboratories, analysts

	No. 380 3-foot 6-inch bed Per cent	No. 381 7-foot 2-inch zone Per cent
Silica, SiO_2	23.26	11.43
Alumina, Al_2O_3	5.92	3.09

Ferric oxide, Fe_2O_3	0.38	0.74
Ferrous oxide, FeO	2.57	0.95
Iron disulphide, FeS_2	<0.01	<0.01
Magnesium oxide, MgO	10.22	5.71
Calcium oxide, CaO	22.92	38.88
Strontium oxide, SrO	<0.01	<0.01
Barium oxide, BaO	0.13	0.06
Sodium oxide, Na_2O	0.04	0.22
Potassium oxide, K_2O	0.16	0.44
Water, hydroscopic, H_2O-	0.38	0.43
Water, combined, H_2O+	4.19	0.38
Carbon dioxide, CO_2	28.88	36.64
Titanium dioxide, TiO_2	0.02	0.14
Phosphorus pentoxide, P_2O_5	0.02	0.22
Sulphur trioxide, SO_3	0.65	0.14
Manganous oxide, MnO	0.17	0.02
Carbon, organic, C	0.11	0.55
Hydrogen, organic, H	0.01	0.06
Total	100.03	100.10

The per cent of each of the compounds probably present in Sample No. 380 has been computed (Lamborn) from the chemical analysis

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.85
Silicates $Al_2O_3.2SiO_2.2H_2O$	13.17
Silica, SiO_2	16.29
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.44
Ferrous carbonate, $FeO.CO_2$	4.14
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO.P_2O_5$	0.04
Calcium sulphate, $CaO.SO_3$	0.99
Barium sulphate, $BaO.SO_3$	0.20
Calcium carbonate, $CaO.CO_2$	40.14
Magnesium carbonate, $MgO.CO_2$	21.36
Manganese carbonate, $MnO.CO_2$	0.27
Water, hydroscopic, H_2O-	0.38
Organic matter	0.12
Unbalanced components (deficiency CO_2, H_2O)	+0.62
Total	100.03

The analysis of Sample No. 381 computed (Lamborn) to per cent of each of compounds probably present is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	6.43
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.46
Silica, SiO_2	7.79
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.87
Ferrous carbonate, $FeO.CO_2$	1.53
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.14
Calcium phosphate, $3CaO.P_2O_5$	0.48
Calcium sulphate, $CaO.SO_3$	0.19
Barium sulphate, $BaO.SO_3$	0.09
Calcium carbonate, $CaO.CO_2$	68.79
Magnesium carbonate, $MgO.CO_2$	11.93
Manganese carbonate, $MnO.CO_2$	0.03
Water, hydroscopic, H_2O-	0.43
Organic matter	0.61

Unbalanced components (excess CO_2, H_2O)	-0.67
Total	100.10

Benwood - Arnoldsburg - Uniontown Limestones

The Meigs Creek coal in Noble County is generally closely overlain by beds of sandstone and sandy shale ranging in thickness from 5 to 40 or 50 feet. Above these sandstones and shales and extending to the Uniontown coal is a series of calcareous shales with varying amounts of interbedded limestone representing in ascending order the Benwood, Arnoldsburg, and Uniontown members. Owing to the poor development of the Fulton Green shale and the Arnoldsburg sandstone, on the outcrop, these three limestone members can not be readily distinguished from each other in this county. The distribution of outcrops of these limestones includes the high hills and ridges in Beaver, Marion, Stock, Jefferson, Enoch, southeastern Seneca, and southeastern Center townships in the eastern and southeastern parts of the county; and Jackson, southwestern Olive, Sharon, and southwestern Brookfield townships in the southwestern part of the county. In the eastern and southeastern sections the limestones above the Meigs Creek coal have not been utilized to any extent owing to the wide distribution of the Fishpot limestone which outcrops lower on the hillsides and which generally contains less interstratified shale. In Jackson, Olive, and Sharon townships in the southwestern part of the county the limestones between the Meigs Creek and Uniontown coals have been quarried at a few localities for road stone and for agricultural limestone.

Limestone, probably Benwood in age, was formerly quarried in the northeast quarter of Section 27, Sharon Township, and was sold for road stone. This old quarry, where about 10 feet of limestone and interstratified shale is exposed, is located along the east-west road just west of Olive Green Creek at an altitude of approximately 880 feet. The beds exposed here as well as those outcropping along the gutter both above and below the quarry are described in the following section.

		Ft.	In.
Shale, yellow, calcareous, with three or four thin, marly limestone layers		4	8
Shale, reddish brown, soft, calcareous, with a few limestone nodules		5	4
Limestone, light brownish gray, dense, one layer, sampled	Benwood	-	7
Shale, bluish gray, calcareous, not sampled	Benwood	-	5
Limestone, bluish to brownish gray, dense, one layer, sampled	Benwood	-	11
Shale, yellowish brown, calcareous, not sampled	Benwood	1	5
Limestone, bluish to brownish gray, dense, hard, sampled	Benwood	1	0
Shale, calcareous, not sampled	Benwood	-	3

Limestone, light brownish gray, hard, one layer, sampled......	Benwood (cont.)	....	-	3
Shale, calcareous, not sampled.........		....	-	5
Limestone, light brownish gray, dense texture, tough, one layer, sampled......		....	1	2
Shale, gray, calcareous, not sampled		....	-	10
Limestone, light brownish gray, dense texture, tough, hard, one layer, sampled		....	2	6
Bottom of quarry.				

	Ft.	In.
Shale, light greenish gray, with a few thin beds of impure ferruginous limestone	11	0
Limestone, dark bluish gray..........................	2	4
Shale, light green, calcareous, with a few thin irregular limestone layers...............................	10	0

The limestone layers exposed in this quarry having a total combined thickness of 6 feet 5 inches were sampled by R. E. Lamborn on August 15, 1941, for chemical analysis.

Sample No. 374

Chemical analysis of Benwood? limestone from old quarry in Section 27, Sharon Township, Noble County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	8.08
Alumina, Al_2O_3	2.72
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO..	0.42
Iron disulphide, FeS_2	0.04
Magnesium oxide, MgO..	3.59
Calcium oxide, CaO..	44.48
Strontium oxide, SrO..	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O..	0.02
Potassium oxide, K_2O..	0.10
Water, hydroscopic, H_2O-..	0.49
Water, combined, H_2O+	0.75
Carbon dioxide, CO_2	39.04
Titanium dioxide, TiO_2..	0.08
Phosphorus pentoxide, P_2O_5	0.06
Sulphur trioxide, SO_3	0.02
Manganous oxide, MnO..	0.12
Carbon, organic, C..	0.02
Hydrogen, organic, H..	--
Total	100.05

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.09
Silicates $Al_2O_3.2SiO_2.2H_2O$	5.81
Silica, SiO_2	4.88
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	0.68
Iron disulphide, FeS_2	0.04
Titanium dioxide, TiO_2	0.08
Calcium phosphate, $3CaO.P_2O_5$	0.13
Calcium sulphate, $CaO.SO_3$	0.03
Calcium carbonate, $CaO.CO_2$	79.24
Magnesium carbonate, $MgO.CO_2$	7.50
Manganese carbonate, $MnO.CO_2$	0.20
Water, hydroscopic, H_2O-	0.49
Organic matter	0.02
Unbalanced components (excess CO_2, H_2O)	-0.16
Total	100.05

The Benwood-Uniontown limestone has been quarried on a small scale for agricultural use on the B. W. Willey property in the east central part of Section 32, Olive Township. The rock formation here consists of layers of limestone ranging from a few inches to more than 2 feet in thickness separated by thin beds of shale. A detailed description of the exposures in the quarry is as follows:

		Ft.	In.
Clay shale, calcareous, weathered, not sampled		1	6
Limestone, bluish gray, sampled	Benwood-Uniontown	-	9
Clay shale, calcareous, not sampled	Benwood-Uniontown	-	8
Limestone, bluish gray, dense-textured, tough, sampled	Benwood-Uniontown	1	4
Marly layer, soft, yellowish brown, not sampled	Benwood-Uniontown	1	0
Clay shale, calcareous, not sampled	Benwood-Uniontown	1	0
Limestone, light bluish gray, dense-textured, sampled	Benwood-Uniontown	1	1
Shale, calcareous, not sampled	Benwood-Uniontown	1	1
Limestone, gray to brownish gray, sampled	Benwood-Uniontown	1	10
Shale, not sampled	Benwood-Uniontown	-	2
Limestone, light bluish gray, dense texture, sampled	Benwood-Uniontown	-	6

			Feet	Inches
Shale, yellow brown, calcareous, not sampled	Benwood-Uniontown (cont.)	....	-	2
Limestone, light bluish gray, dense texture, sampled		....	-	9
Limestone, light brownish gray, dense texture, sampled, brittle		....	1	0
Clay shale, gray, with limestone nodules, not sampled		....	1	3
Limestone, bluish to light brownish gray, sampled.....		....	2	7
Shale, buff, calcareous, not sampled		....	-	6 1/2
Limestone, bluish gray, dense texture, brittle, sampled		....	2	4

Bottom of quarry.

The limestone layers quarried here having a total thickness of 13 feet 6 inches were sampled by R. E. Lamborn on June 12, 1942. The analysis follows:

Sample No. 382

Chemical analysis of Benwood-Uniontown limestone from quarry on B. W. Willey property, Section 32, Olive Township, Noble County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	12.47
Alumina, Al_2O_3	2.35
Ferric oxide, Fe_2O_3	1.00
Ferrous oxide, FeO..	0.65
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO..	6.35
Calcium oxide, CaO..	38.88
Strontium oxide, SrO..	<0.01
Barium oxide, BaO	0.14
Sodium oxide, Na_2O..	0.25
Potassium oxide, K_2O..	0.10
Water, hydroscopic, H_2O-..	0.36
Water, combined, H_2O+	0.57
Carbon dioxide, CO_2	36.11
Titanium dioxide, TiO_2..	0.08
Phosphorus pentoxide, P_2O_5	0.19
Sulphur trioxide, SO_3	0.09
Manganous oxide, MnO..	0.01
Carbon, organic, C..	0.50
Hydrogen, organic, H..	0.06
Total	100.16

The per cent of each of the chief mineral constituents probably present in the sample as computed (Lamborn) from the chemical analysis is as follows:

Silicates	$(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	3.93
	$Al_2O_3.2SiO_2.2H_2O$	2.00
Silica, SiO_2		9.70
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$		1.17
Ferrous carbonate, $FeO.CO_2$		1.05
Iron disulphide, FeS_2		<0.01
Titanium dioxide, TiO_2		0.08
Calcium phosphate, $3CaO.P_2O_5$		0.41
Calcium sulphate, $CaO.SO_3$		0.03
Barium sulphate, $BaO.SO_3$		0.21
Calcium carbonate, $CaO.CO_2$		68.97
Magnesium carbonate, $MgO.CO_2$		13.27
Manganese carbonate, $MnO.CO_2$		0.02
Water, hydroscopic, H_2O-		0.36
Organic matter		0.56
Unbalanced components (excess CO_2, H_2O)		-1.60
Total		100.16

The Benwood limestone was formerly quarried in a small scale for road stone in the northwest quarter of Section 27,. Jackson Township. The quarry is located near stream level just east of the northwest-southeast road and close to the north boundary of the section. The beds exposed are described below.

		Ft.	In.
Shale and covered		2	0
Limestone, bluish gray, tough, one bed, sampled	Benwood	-	6
Limestone, bluish to brownish gray, dense, tough, one layer, sampled	Benwood	1	6
Limestone, bluish gray, brittle, flint-like fracture, one layer, sampled	Benwood	2	0
Limestone, bluish gray, compact but somewhat brecciated, dense texture, brittle, sampled	Benwood	4	0
Bottom of quarry.			

The 8 feet of limestone exposed in this quarry was sampled by R. E. Lamborn on June 11, 1942, for chemical analysis.

Sample No. 379

Analysis of Benwood limestone from abandoned quarry northwest part of Section 27, Jackson, Noble County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	15.46

Alumina, Al_2O_3	3.53
Ferric oxide, Fe_2O_3	0.45
Ferrous oxide, FeO	0.81
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	5.94
Calcium oxide, CaO	36.93
Strontium oxide, SrO	<0.01
Barium oxide, BaO	0.08
Sodium oxide, Na_2O	0.03
Potassium oxide, K_2O	0.01
Water, hydroscopic, H_2O-	0.39
Water, combined, H_2O+	0.95
Carbon dioxide, CO_2	34.13
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.04
Sulphur trioxide, SO_3	0.21
Manganous oxide, MnO	0.05
Carbon, organic, C	1.01
Hydrogen, organic, H	0.16
Total	100.19

The per cent of each of the compounds probably present in Sample No. 379 as computed (Lamborn) from the chemical analysis is as follows:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.45
Silicates $Al_2O_3.2SiO_2.2H_2O$	8.48
Silica, SiO_2	11.30
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.53
Ferrous carbonate, $FeO.CO_2$	1.30
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.01
Calcium phosphate, $3CaO.P_2O_5$	0.09
Calcium sulphate, $CaO.SO_3$	0.29
Barium sulphate, $BaO.SO_3$	0.12
Calcium carbonate, $CaO.CO_2$	65.62
Magnesium carbonate, $MgO.CO_2$	12.41
Manganese carbonate, $MnO.CO_2$	0.08
Water, hydroscopic, H_2O-	0.39
Organic matter	1.17
Unbalanced components (excess CO_2, H_2O)	-2.05
Total	100.19

Waynesburg Limestone

The known occurrence of the Waynesburg limestone in Noble County is confined to a few scattered localities in the southern part. Here the member consists of a few beds of dense gray argillaceous limestone interstratified with thin calcareous shale occurring a few feet below the Little Waynesburg coal. No economic importance can be attached to this limestone in Noble County.

Elm Grove Limestone

The Elm Grove limestone, which in normal succession is found a few feet above the Waynesburg coal, is not well represented in this county. In the southern part, where the hills are high enough to include some Permian strata near their summits, the Elm Grove limestone is wanting in some areas. Where present it is generally represented by dark blue fossiliferous beds ranging in thickness from a few inches to 2 feet. Its economic importance is negligible.

Mount Morris Limestone

Scattered exposures of the Mount Morris member have been recognized near the hilltops in a few localities in southern Noble County. Where present it is represented by nodules or a few thin beds of limestone occurring close below the Little Waynesburg coal and about 45 feet on an average above the Waynesburg coal. It has no economic importance in this county.

PERRY COUNTY

General Considerations

Perry County representing an area of about 412 square miles contains within its boundaries outcrops of beds belonging to the Mississippian system and to the Pottsville, Allegheny, and Conemaugh series of the Pennsylvanian system. The total thickness of the beds outcropping in this county is a little more than 700 feet. Located as it is well down the eastern flank of the Cincinnati arch, the general dip of the beds in this county is in a direction south of east. Consequently the youngest series exposed, the Conemaugh, is present only in the east central and southeastern parts whereas progressively older beds reach the surface to the northwest. Outcrops of the oldest strata exposed, represented by sandstones and shales of Vinton age, are confined in their distribution to the northwest corner, to the valley of Jonathan Creek and its tributaries in the central northern part, and to the valleys and tributary valleys of Rush Run, Little Rush Run, and Turkey Run in the western part. An average section of the beds exposed in Perry County showing the various limestone, coal, clay, and sandstone members with average thickness of each is as follows [1].

Average Section of Bedrocks Outcropping In Perry County

	Ft.	In.
Pennsylvanian system		
Conemaugh series		
Shale and sandstone	50	0
Limestone, greenish gray crystalline, fossiliferous, Ames	1	9
Shale, varicolored, calcareous	2	0
Coal, almost wanting, Harlem	-	4
Clay	1	0
Shale, buff, sandy, to red, argillaceous; sandstone locally present	25	0
Coal, wanting, Barton	-	-
Limestone, gray to greenish, dense, ferruginous, micaceous, in places nodular, Ewing	4	6
Shale, buff to red, with local deposits of sandstone; Cow Run sandstone horizon	30	0
Clay shale, dark gray, fossiliferous, with nodules and lentils of fossiliferous limestone, Portersville	4	6
Coal, good, locally shaly, Anderson	1	0
Shale, variegated, somewhat sandy	15	0
Limestone, gray to buff, crystalline, locally nodular, Cambridge	2	0
Coal, wanting, Wilgus	-	-

[1] *The average section and some data on the distribution of the limestones in Perry County has been derived from an unpublished manuscript on the Geology of Perry County by N. K. Flint.*

Clay, wanting	-	-
Shale, variegated in color, Buffalo sandstone horizon	33	0
Limestone, gray, buff to greenish, crystalline, occasionally ferruginous and dense, Brush Creek	2	0
Shale, buff to greenish, generally sandy	17	0
Coal, generally shaly, Mason	-	6
Clay, gray, plastic	3	0
Shale, sandy, and shaly sandstone, Upper Mahoning sandstone horizon	30	0
Coal, generally bony to shaly, Mahoning	-	10
Clay, gray, greenish, brick red, and purplish, plastic, Thornton	5	6
Limestone, gray to greenish gray, nodular to bedded, not persistent, Mahoning	4	6
Sandstone, massive, cross-bedded, micaceous, grading to shale, Lower Mahoning	35	0
Allegheny series		
Coal, locally present, Upper Freeport	1	6
Clay, gray, plastic, locally sandy	5	0
Limestone, dark gray, dense, somewhat brecciated, Upper Freeport	2	0
Clay, gray, generally plastic, Bolivar	5	6
Shale and interbedded sandstone, Upper Freeport	20	0
Coal good at base, shaly in upper part, Lower Freeport	1	6
Clay, gray, plastic, somewhat sandy, with limestone and iron carbonate nodules	4	0
Limestone, gray, sandy, ferruginous, nodular, in clay shale, Lower Freeport	6	0
Shale, gray, sandy, with local deposits of sandstone, Lower Freeport sandstone horizon	25	0
Coal, Middle Kittanning	5	6
Clay, bluish gray, plastic, sandy, with iron carbonate nodules	4	0
Coal to carbonaceous shale, Strasburg	-	4
Clay, plastic, sandy, with ferruginous and calcareous nodules, Oak Hill	7	0
Shale, with local deposits of sandstone	10	0
Shale, fossiliferous, with nodules of ferruginous, fossiliferous limestone, Hamden	4	0
Coal, good, Lower Kittanning	2	0
Clay, gray, plastic, a little sandy	5	0
Shale, gray, and/or medium-grained sandstone	6	0
Ironstone, Ferriferous	-	6
Flint, limestone, or fossiliferous shale, Vanport	1	0
Sandstone, local	9	0
Coal and carbonaceous shale, local, Clarion	-	6
Clay, gray, plastic, somewhat sandy	3	0
Shale, gray, with local bodies of sandstone, Clarion sandstone horizon	42	0

Limestone, bluish gray, fossiliferous, flinty, in places replaced by fossiliferous shale, Putnam Hill	1	6
Coal, often bony and shaly, Brookville	-	7
Pottsville series		
Clay, gray, plastic	4	0
Sandstone, massive, coarse-grained, grading laterally to micaceous friable sandstone and to shale, Homewood sandstone horizon	15	0
Coal, often bony to shaly, Tionesta	-	6
Clay, gray, plastic, locally sandy	6	6
Sandstone and shale, locally present	5	0
Limestone and flint, locally present, Upper Mercer	2	0
Coal, often bony and shaly, or carbonaceous shale, Bedford	-	9
Clay, gray, plastic, locally siliceous and ferruginous	3	0
Shale and sandstone	17	0
Limestone, dark bluish gray, fossiliferous, flinty in places, Lower Mercer	2	0
Shale, dark gray, calcareous, fossiliferous	-	8
Coal, somewhat bony, carbonaceous shale in places, Middle Mercer	1	0
Clay, gray, plastic, sandy	3	6
Shale and sandstone	4	0
Coal to black carbonaceous shale, Flint Ridge	1	0
Clay, gray, plastic, locally arenaceous, with clay ironstone concretions	4	0
Shale, argillaceous to sandy with local deposits of sandstone	13	0
Flint, occasionally fossiliferous with some ironstone, Boggs	1	0
Coal, occasionally bony or carbonaceous shale, wanting in places, Lower Mercer	1	0
Clay, gray, sandy	3	6
Shale and sandstone	10	0
Coal, somewhat bony or carbonaceous shale, Vandusen	1	0
Clay, gray, plastic, siliceous, ferruginous	3	6
Shale, gray, sandy, and gray medium-grained sandstone	10	0
Coal, sometimes bony or carbonaceous shale, Bear Run	1	0
Clay, gray, plastic, somewhat siliceous and ferruginous	3	0
Sandstone, light gray to brownish, medium-bedded to massive, somewhat cross-bedded, Massillon	20	0
Coal, somewhat bony to thick carbonaceous shale, Quakertown	4	0
Clay, gray, sandy, ferruginous	2	6
Shale, gray, sandy, with ironstone nodules and some interbedded sandstone	8	0
Coal, somewhat shaly, Huckleberry	-	4
Clay, gray, plastic	1	0
Shale, gray, sandy, and medium-grained sandstone	11	0

Coal to carbonaceous shale, Anthony	-	8
Clay, gray, plastic, Sciotoville	4	0
Shale and sandstone	7	0
Porous cherty material, containing rounded quartz pebbles and impregnated with limonite, Harrison	-	5
Mississippian system		
Limestone, gray to light buff, fossiliferous, often dolomitic and sandy in lower part, Maxville formation, maximum thickness	42	0
Sandstone, gray, fine-grained, thin-bedded, generally interstratified with shale, Vinton member of Cuyahoga formation	100	0

As indicated in the average section, fourteen limestone-bearing horizons have been recognized in the bedrock outcrops in Perry County. The limestones, however, are generally patchy and discontinuous on the outcrop and, with the possible exception of the Maxville, are too thin for more than small scale quarry operations to supply local needs. In addition to the Maxville, the Lower Mercer, Upper Freeport, and Brush Creek limestones have been quarried from time to time either for their lime content or for the production of crushed stone for road construction and repair. Most of these quarries have been abandoned.

Below the Maxville limestone, shale and sandstone extend downward in vertical section for many hundreds of feet. In wells drilled for oil and gas the Middle Devonian limestones, the next important limestone series below the Maxville, is first encountered at depths below sea level ranging from 500 feet in the northwestern part of Thorn Township to approximately 1,800 feet in the southeastern part of Monroe Township.

Maxville Limestone

The horizon of the Maxville limestone reaches the surface along a sinuous line extending through the western and northern parts of Perry County. Known deposits of limestone on this horizon, however, are limited to a few localities only, as this formation was in large part removed by erosion occurring at the end of the Mississippian period and preceding the deposition of the clastic beds of the lower Pennsylvanian. Outcrops of the Maxville limestone are confined to the valley of Monday Creek in the south central part of Monday Creek Township, to small areas in the southwestern and western parts of Reading Township, to a few scattered localities in southwestern Hopewell Township and eastern Thorn Township, and to the valley of Jonathan Creek in east central Madison Township. The thickness on the outcrop varies from a few inches to a known maximum in this county of about 42 feet. The stone ranges in physical structure from a regular bedded limestone to one which is nodular in appearance or to nodular limestone embedded in calcareous shale. In composition the changes include variations from a limestone of high purity to one which is argillaceous or is highly arenaceous or siliceous. [1] The Maxville limestone was formerly quarried along the outcrop near Maxville, Monday Creek Township, and was sold for flux stone. It has likewise been worked at a few localities along the outcrop in the southwestern part of Reading Township and the stone has been utilized chiefly for road construction.

In the eastern part of Perry County more or less isolated remnants of Maxville limestone are indicated in records of wells drilled to the Berea and Clinton

[1] *Morse, W. C., The Maxville limestone: Geol. Survey Ohio Bull. 13, pp. 65-78, 1910.*

sands for oil and gas. Known to the driller as the "lime" or "junglerock," a thickness ranging from a few feet to as much as 60 feet has been reported in records of wells drilled at widely scattered localities in Monroe, Pleasant, Bearfield, eastern Clayton, and Harrison townships. The depth to the limestone in these areas varies in general from 125 feet to 475 feet. The largest and most continuous remnant occurs in northern Harrison Township where this limestone varying from 20 to 50 feet in thickness is reached at depths ranging from 125 feet to about 400 feet.

In recent years the Maxville limestone has been quarried by Stillwell Brothers on the E. E. Venatta property in the north central part of Section 25, Reading Township. The quarry is located just south of the public road at the headwaters of a small southern-flowing tributary to Little Rush Creek. The stone has been utilized chiefly for road construction although small quantities have been marketed for agricultural use. A record of the exposures in the quarry is as follows:

		Ft.	In.
Shale and covered, estimated thickness	Maxville	10	0
Limestone, yellow brown, thin-bedded, arenaceous, impure, not sampled		6	0
Limestone, gray to bluish gray, thick-bedded, arenaceous, sampled		4	6
Clay shale, soft, with some nodular limestone, not sampled		-	3
Limestone, light bluish gray, sampled		-	4
Shale, calcareous, not sampled		-	1
Limestone, light bluish gray, one layer, sampled		1	6
Shale, with a thin limestone layer, not sampled		-	2
Limestone, gray to bluish gray, sampled		-	6
Shale, gray, calcareous, not sampled		-	3
Limestone, gray, compact, sampled		-	10
Bottom of quarry.			

The lower part of the Maxville limestone exposed in this quarry, having a thickness of 7 feet 8 inches as described in the section above, was sampled by R. E. Lamborn on August 10, 1943, for chemical analysis.

Sample No. 413

Chemical analysis of Maxville limestone from quarry of Stillwell Brothers, Section 25, Reading Township, Perry County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	7.83
Alumina, Al_2O_3	1.77
Ferric oxide, Fe_2O_3	0.20
Ferrous oxide, FeO	1.91
Iron disulphide, FeS_2	0.19
Magnesium oxide, MgO	5.73
Calcium oxide, CaO	41.45
Sodium oxide, Na_2O	0.04
Potassium oxide, K_2O	0.40
Water, hydroscopic, H_2O-	0.11
Water, combined, H_2O+	0.55
Carbon dioxide, CO_2	39.31
Titanium dioxide, TiO_2	0.09
Phosphorus pentoxide, P_2O_5	0.04
Sulphur trioxide, SO_3	0.13
Manganous oxide, MnO	0.12
Total	99.87

The per cent of each of the mineral components in Sample No. 413 as calculated (Lamborn) from the chemical analysis is given below:

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	3.87
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.67
Silica, SiO_2	5.75
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.23
Ferrous carbonate, $FeO.CO_2$	3.08
Iron disulphide, FeS_2	0.19
Titanium dioxide, TiO_2	0.09
Calcium phosphate, $3CaO.P_2O_5$	0.09
Calcium sulphate, $CaO.SO_3$	0.22
Calcium carbonate, $CaO.CO_2$	73.73
Magnesium carbonate, $MgO.CO_2$	11.98
Manganese carbonate, $MnO.CO_2$	0.19
Water, hydroscopic, H_2O-	0.11
Unbalanced components (excess CO_2, H_2O)	-0.35
Total	99.87

The entire thickness of the Maxville limestone is well exposed near water level along the east bank of Monday Creek on the Howdysell property in the northeast quarter of Section 20, Monday Creek Township, Perry County. A description of the exposures as recorded by Wilber Stout at this locality is as follows:

	Ft.	In
Shale	20	0
Coal smut, Anthony	-	3
Clay, gray, plastic, sandy, Sciotoville	2	1
Shale, dark, fissile	2	2
Shale, dark gray	6	6
Ore, Harrison	-	2 1/2
Shale, calcareous	-	6

Limestone, irregular, sandy, reworked, not sampled	Maxville	....	-	6 to 10
Limestone, dark, somewhat irregular, parts sandy, reworked, sampled		....	1	6
Limestone, light, hard, shaly, sampled......		....	1	3
Limestone, light, hard, conchoidal fracture, sampled		....	-	2
Limestone, pure, sampled		....	-	7
Limestone, pure, sampled		....	-	9
Limestone, pure, sampled		....	--	5 3/4
Limestone, pure, sampled		....	-	8 1/2
Limestone, pure, sampled		....	-	6 1/2
Limestone, pure, sampled		....	-	3 1/2
Limestone, pure, sampled		....	-	6
Limestone, ferruginous, very irregular, brecciated, varies from 7 to 16 inches, not sampled			-	9
Sandstone and shale, Waverly			-	-

The Maxville limestone at this locality, excluding the top and bottom layers, having a thickness of 6 feet 9 1/4 inches, was sampled by Wilber Stout for chemical analysis on June 25, 1941.

Sample No. 351

Chemical analysis of Maxville limestone from outcrop on Howdysell property, Section 20, Monday Creek Township, Perry County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	2.41
Alumina, Al_2O_3	0.70
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO..	1.11
Iron disulphide, FeS_2	0.08
Magnesium oxide, MgO..	1.68
Calcium oxide, CaO..	50.96
Strontium oxide, SrO..	$<$0.01
Barium oxide, BaO	$<$0.01
Sodium oxide, Na_2O..	$<$0.01
Potassium oxide, K_2O..	0.01
Water, hydroscopic, H_2O-..	0.15
Water, combined, H_2O+	0.20
Carbon dioxide, CO_2	42.43
Titanium dioxide, TiO_2..	0.05
Phosphorus pentoxide, P_2O_5	0.06
Sulphur trioxide, SO_3	0.06

Manganous oxide, MnO	0.08
Carbon, organic, C	0.02
Total	100.02

The per cent of each of the compounds probably present in the sample has been calculated (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.08
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.69
Silica, SiO_2	1.59
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.79
Iron disulphide, FeS_2	0.08
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO.P_2O_5$	0.13
Calcium sulphate, $CaO.SO_3$	0.06
Calcium carbonate, $CaO.CO_2$	90.82
Magnesium carbonate, $MgO.CO_2$	3.51
Manganese carbonate, $MnO.CO_2$	0.13
Water, hydroscopic, H_2O-	0.15
Organic matter	0.02
Unbalanced components (excess CO_2, H_2O)	-0.10
Total	100.02

Lower Mercer Limestone

The Lower Mercer limestone occurs above drainage over a north south belt extending across Perry County including parts of Hopewell, Madison, Reading, Clayton, Jackson, Pike, Monday Creek, Salt Lick, and Coal townships. It is generally thin in this county consisting for the most part of two beds or layers separated by a thin shale parting, the total varying from a few inches to two feet or so in thickness. At a few places on the outcrop where greater thickness occurs it is represented by a thin bed of limestone overlain by several feet of dark fossiliferous shale. The general chemical character of this limestone is illustrated by the analysis of a sample secured at Union Furnace and described in this report under Hocking County.

Upper Mercer Limestone

The distribution of the Upper Mercer limestone on the outcrop in Perry County is essentially the same as the Lower Mercer previously described as it is found on an average only about 23 feet higher in the section. In character the limestone is typical for this member as it may consist of either black siliceous limestone, black flint, or a combination of the two. A mixture of flint and limestone is the usual mode of occurrence. The observed thickness of the Upper Mercer limestone in this county ranges from a few inches to about 3 feet. Due to its thin development and generally high siliceous character little use has been found for it in this area.

Typical of the Upper Mercer limestone in much of Perry County is the exposure described in the following record of outcrops along the road in the central part of Section 9, Monday Creek Township.

	Ft.	In.
Limestone, bluish gray to black, upper 2 feet very siliceous and cherty, <u>Upper Mercer</u>	3	0

Covered interval	7	6
Shale, gray, arenaceous	15	0
Limestone, bluish gray, shaly, fossiliferous, Lower Mercer	-	4
Shale, dark	2	0
Coal, shaly	-	3
Clay, dark bluish gray, plastic	2	0

The Upper Mercer limestone at this locality, having a thickness on the outcrop of 3 feet, was sampled by R. E. Lamborn on August 11, 1943, for chemical analysis.

Sample No. 414

Chemical analysis of Upper Mercer limestone from outcrop, Section 9, Monday Creek Township, Perry County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	34.58
Alumina, Al_2O_3	0.47
Ferric oxide, Fe_2O_3	0.04
Ferrous oxide, FeO	0.70
Iron disulphide, FeS_2	0.41
Magnesium oxide, MgO	0.51
Calcium oxide, CaO	34.49
Sodium oxide, Na_2O	0.11
Potassium oxide, K_2O	0.09
Water, hydroscopic, H_2O-	0.09
Water, combined, H_2O+	0.40
Carbon dioxide, CO_2	27.40
Titanium dioxide, TiO_2	0.02
Phosphorus pentoxide, P_2O_5	0.16
Sulphur trioxide, SO_3	0.14
Manganous oxide, MnO	0.08
Total	99.69

The per cent of each of the mineral components in Sample No. 414 as calculated (Lamborn) from the chemical analysis is given below:

Silica and hydrated aluminum silicates of sodium and potassium	35.64
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.05
Ferrous carbonate, $FeO.CO_2$	1.13
Iron disulphide, FeS_2	0.41
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO.P_2O_5$	0.35
Calcium sulphate, $CaO.SO_3$	0.24
Calcium carbonate, $CaO.CO_2$	61.04
Magnesium carbonate, $MgO.CO_2$	1.06
Manganese carbonate, $MnO.CO_2$	0.13
Water, hydroscopic, H_2O-	0.09
Unbalanced components (excess CO_2)	-0.47
Total	99.69

Putnam Hill Limestone

The Putnam Hill has little importance for its limestone content in Perry County. Along its line of outcrop, which extends from Madison and Harrison townships on the north to Monday Creek Township on the south, this member may be represented by thin limestone, by nodular limestone in shale, or by fossiliferous shale. The limestone phase is probably best developed in Harrison Township in the northeast part of the county where the thickness may reach a maximum of 2 or 3 feet. For composition of this limestone in its field of best development see sections of this report dealing with Coshocton, Holmes, and Stark counties.

Vanport Limestone

The Vanport limestone, which reaches its maximum development in Ohio in southern Vinton, eastern Jackson, Lawrence, and eastern Mahoning counties, is represented in Perry County by only occasional deposits of thin limestone and chert. In the absence of the Vanport its horizon is in places marked by nodular ore representing the Ferriferous horizon. No economic importance is attached to this limestone in Perry County.

Hamden Member

The Hamden member has no economic importance in Perry County as it has been identified at only one locality where it is represented by thin nodular ferruginous limestone embedded in fossiliferous shale.

Lower Freeport Limestone

The Lower Freeport limestone merits little attention in Perry County as it is thin, impure, and discontinuous. In east central Salt Lick Township and west central Monroe Township, where it occurs in best development, this member consists for the most part of nodules of sandy ferruginous limestone embedded in calcareous shale. The maximum thickness approximates 10 feet, but only a small per cent is limestone. This limestone adds little to the potential mineral resources of the county.

Upper Freeport Limestone

The stratigraphic horizon of the Upper Freeport limestone outcrops in parts of every township in the southeast half of Perry County, but the limestone lacks continuity. According to Flint [1] the exposures are limited to the outcrops in Coal, Salt Lick, and Monroe townships, where the limestone is a persistent member with an average thickness of about 2 feet. Here it is a dense, hard, gray to bluish gray stone which often has a brecciated appearance. It was formerly quarried at several places near Shawnee where it was known as the Shawnee limestone, and where it was utilized as a flux stone in the early iron furnaces. [2] It is not being utilized at the present time.

Mahoning Limestone

Similar in general character and mode of occurrence to the Freeport limestones previously described is the Mahoning limestone occurring a few feet below the Mahoning coal and 35 feet on an average above the Upper Freeport coal. Like

[1] *Flint, N. K., op. cit.*

[2] *Andrews, E. B., Supplementary report on Perry County and portions of Hocking and Athens counties: Geol. Survey Ohio Vol. III, p. 874, 1878.*

the Freeport limestones, the Mahoning is lacking in continuity. Scattered occurrences are present along the crop line of its horizon, however, from Harrison Township to Coal and Monroe townships. The limestone is dense with a gray to bluish gray color and occurs both as nodules and thin lens-like layers embedded in calcareous clay shale. The member adds little to the potential limestone resources of the county.

Brush Creek Limestone

The Brush Creek is the lowest limestone member of the Conemaugh possessing any continuity on the outcrop in Perry County. Here its distribution is confined to the southeastern quarter of the county including parts of Salt Lick, Coal, Bearfield, Monroe, Pleasant, and Harrison townships. The stratigraphic position of the limestone is on an average about 97 feet above the well-known Upper Freeport coal. "In the northeastern corner of the county, it is a cherty, sandy, fossiliferous limestone in a number of layers, having a total thickness of over five feet. But to the southward the rock loses its cherty appearance and is a gray limestone with rusty brown spots, and with a thickness of less than two feet." [1] The maximum known thickness in Perry County of about 10 feet occurs along the Perry-Morgan County line in the northeastern part of Bearfield Township. [2] Here the limestone, which is cherty and impure, has been quarried and utilized for road construction and repair.

Cambridge Limestone

The Cambridge limestone lacks economic importance in Perry County. It is widely distributed on the outcrop but it lacks continuity. Where present it is generally represented by nodular masses of dark gray dense to finely crystalline limestone embedded in calcareous clay shale, the whole ranging from a few inches to 3 or 4 feet in thickness. As the member occurs on an average about 35 feet above the Brush Creek limestone, its areal distribution in the county is essentially the same as for that limestone. Analyses of Cambridge limestone in Ohio are given in parts of this report dealing with Columbiana, Muskingum, Meigs, Gallia, and Lawrence counties.

Portersville Member

The Portersville member, named by Condit [3] for its occurrence near Portersville, Bearfield Township, consists chiefly of dark fossiliferous shale in Perry County. Thin dark nodular fossiliferous limestone is often found embedded in the shale. Immediately below this shale and limestone member is the conspicuous Anderson coal. Owing to its high content of shale little importance can be attached to the Portersville in this county for its lime content.

Ewing Limestone

Another limestone which lacks persistence in extent, thickness, and lithology is the Ewing limestone which in southeastern Bearfield Township and eastern Monroe Township outcrops about 50 feet above the Cambridge limestone and about 33 feet below the Ames limestone. In character it is generally a gray to greenish

[1] *Condit, D. D., Conemaugh formation in Ohio: Geol. Survey Ohio Bull. 17, pp. 124-125, 1912.*

[2] *Flint, N. K., op. cit.*

[3] *Condit, D. D., op. cit., pp. 41-42.*

gray dense, ferruginous micaceous, sandy limestone which in places is nodular in calcareous shale and at other places occurs as a distinct bed. According to Flint [1] the thickness of the limestone and associated shale varies from 3 feet to 8 feet but averages 4 feet 6 inches. Owing to its local development and impure character, the Ewing adds little to the potential limestone resources in the county.

Ames Limestone

The Ames limestone is a persistent member in Perry County occurring generally as a single bed varying from a few inches to 2 feet or more in thickness and outcropping on an average about 120 feet above the Brush Creek limestone previously described. The lithologic characteristics are typical for this limestone over large areas of outcrop in eastern Ohio. The outcrops in Perry County are confined chiefly to the high ridges east of Sunday Creek and Dodson Creek in southeastern Bearfield Township and eastern Monroe Township from which areas they extend into western Morgan County. The Ames limestone has not been utilized to any extent in this county. For an analysis of the Ames see sections of this report dealing with this member in Morgan County.

PORTAGE COUNTY

General Considerations

In Portage County the bedrocks which reach the surface belong to the Cuyahoga formation of the Mississippian system and to the Pottsville series of the Pennsylvanian system. As the region is covered with glacial drift, extensive rock exposures are wanting. Outcrops of Cuyahoga shales and sandstones are confined to the valley of Tinkers Creek in western Aurora and northwestern Streetsboro townships in the northwestern corner of the county and to the Grand River and Mahoning River valleys in Nelson and eastern Paris townships in the northeastern part of the county. In the remainder of the area the drift is generally underlain by beds of Pottsville age. Of these the Lower Mercer and Upper Mercer are the only limestones worthy of mention and they are of uncertain thickness and continuity.

Below the Cuyahoga shales, the lowest beds reaching the surface in Portage County, no limestones or dolomites occur until the Middle Devonian series is encountered at depths below sea level ranging from about 900 feet in the northwest corner to 1,900 feet in the southeast corner of the county.

Lower Mercer Limestone

The Lower Mercer limestone is of somewhat uncertain distribution in Portage County. The horizon of this member occurs not far below the general level of the surface in Deerfield, Palmyra, Edinburg, Atwater, Randolph, and Rootstown townships in the southern part of the county, and also along Limestone Ridge in western Freedom Township. In many places in this field the limestone may be wanting, however, owing to lack of deposition or as a consequence of glacial scour preceding the deposition of the drift sheet. The valleys in this area are generally carved in unconsolidated materials leading to few rock outcrops. The Lower Mercer limestone has been reported to crop out in Atwater Township and it has been penetrated in wells drilled near Edinburg, Edinburg Township. [2] The limestone varies in thickness from 0 to about 3 feet.

[1] *Flint, N. K., op. cit.*

[2] *Newberry, J. S., Geology of Portage County: Geol. Survey Ohio Vol. III, p. 145, 1878.*

The Lower Mercer limestone comes to the surface along the valley of Willow Run in the western part of Deerfield Township and the eastern edge of Atwater Township. Here the stone was formerly quarried in a small way and utilized for road construction. A section of the exposures follows:

	Ft.	In.
Coal blossom, Bedford	3	0
Covered interval	30	0
Limestone, dark bluish gray, fossiliferous, Lower Mercer	3	0
Shale, bluish, (fissile), sandy	0	9
Clay, dark, arenaceous	2	6
Shale, dark bluish gray, arenaceous	4	0

The Lower Mercer limestone was sampled at this locality by R. E. Lamborn on July 13, 1943, for chemical analysis.

Sample No. 408

Chemical analysis of Lower Mercer limestone from outcrop along Willow Run, Atwater Township, Portage County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	0.81
Alumina, Al_2O_3	0.27
Ferric oxide, Fe_2O_3	0.04
Ferrous oxide, FeO	2.14
Iron disulphide, FeS_2	0.32
Magnesium oxide, MgO	0.83
Calcium oxide, CaO	51.73
Sodium oxide, Na_2O	0.05
Potassium oxide, K_2O	0.04
Water, hydroscopic, H_2O-	0.08
Water, combined, H_2O+	0.46
Carbon dioxide, CO_2	42.29
Titanium dioxide, TiO_2	0.02
Phosphorus pentoxide, P_2O_5	0.33
Sulphur trioxide, SO_3	0.19
Manganous oxide, MnO	0.13
Total	99.73

The per cent of each of the various mineral components in Sample No. 408 as computed (Lamborn) from the chemical analysis is listed below:

Silica and hydrated aluminum silicates of sodium and potassium	1.62
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.05
Ferrous carbonate, $FeO.CO_2$	3.45
Iron disulphide, FeS_2	0.32
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO.P_2O_5$	0.72
Calcium sulphate, $CaO.SO_3$	0.32
Calcium carbonate, $CaO.CO_2$	91.39
Magnesium carbonate, $MgO.CO_2$	1.74
Manganese carbonate, $MnO.CO_2$	0.21
Water, hydroscopic, H_2O-	0.08
Unbalanced components (excess CO_2)	-0.19
Total	99.73

Upper Mercer Limestone

The Upper Mercer limestone, which normally occurs from 20 to 40 feet above the Lower Mercer limestone previously described, has little importance in Portage County. It is probably the limestone which was formerly quarried on Limestone Ridge in western Freedom Township and burned for quicklime. [1] It is also present over small areas near Edinburg, Edinburg Township, but its areal distribution in other parts of the southern half of the county is in doubt.

RICHLAND COUNTY

General Considerations

Richland County comprising an area of about 499 square miles is located entirely within the area covered by continental glaciation, and glacial drift deposits are therefore widely distributed at the surface. The bedrocks which underlie the drift and which outcrop at many places consist of sandstones, shales, and conglomerates of Mississippian and Pennsylvanian ages. The lowest formation exposed is the Berea sandstone which was formerly quarried at Plymouth in the northwest corner, whereas the youngest beds consist of Pottsville strata which cap the hills in the southeastern part of the area. The total thickness of the outcropping series as indicated by well records is approximately 800 feet. Limestones are not known to occur on the outcrop in Richland County. No thin limestones have been reported in the Pottsville and the Maxville limestone, if ever present in this region, was entirely removed by pre-Pennsylvanian erosion. In the sub-surface succession the first limestones encountered in wells are reached by the drill at levels ranging from 400 feet above tide in the northwest corner of the county to about 475 feet below tide in the southeast corner.

SCIOTO COUNTY [2]

General Considerations

The bedrocks which reach the surface in Scioto County range in age from Upper Devonian to Upper Allegheny and represent a total vertical thickness of approximately 1, 150 feet. Outcrops of Upper Devonian beds represented by the Ohio shale formation are found along the lower slopes in the valley of Scioto Brush Creek in Brush Creek and Rarden townships and along the Ohio River Valley west of the mouth of Carey Run in Nile Township. The Upper Devonian is overlain by sandstones and shales of the Waverly group consisting in ascending order of the Bedford shale, Berea sandstone, Sunbury shale, Cuyahoga shales and sandstones, and Logan shales and sandstones. This clastic series, measuring 600 or 700 feet in thickness, outcrops over a large area in the central and western parts of the county. The limestones which appear at the surface in Scioto County are confined in vertical range to the Maxville formation, remnants of which are found overlying the Waverly, and to the Pottsville and Allegheny series of the Pennsylvanian. These latter beds outcrop over an area of about 115 square miles in the eastern part of the county including part or all of Green, Vernon, Porter, Bloom, Madison, Harrison, Jefferson, and Clay townships. The general succession of members recognized by Wilber Stout in the eastern part of Scioto County is as follows: [3]

[1] *Newberry, J. S., op. cit., p. 142.*

[2] *For a detailed description of the geology of the eastern part of Scioto County see Stout, Wilber, Geology of Southern Ohio: Geol. Survey Ohio Bull 20, pp. 459-598, 1916, from which much data on this county has been secured.*

[3] *Stout, Wilber, op. cit., pp. 465-466: Stout, Wilber, Geology of Vinton County: Geol. Survey Ohio Bull. 31. p. 170, (footnotes) 1927.*

Succession of Members Recognized on the Outcrop in Eastern Scioto County

Pennsylvanian system
Allegheny series
Coal, Middle Kittanning or No. 6
Clay, Middle Kittanning
Ore, Red Kidney
Clay, Oak Hill
Coal, Lost seam
Coal, Lower Kittanning or No. 5
Clay, Lower Kittanning
Ore, Ferriferous
Limestone, Vanport
Coal, Clarion or No. 4a
Clay, Clarion
Ore, Canary
Sandstone, Clarion
Coal, local, Winters
Coal, Brookville or No. 4

Pottsville series
Ore, Upper Mercer
Limestone, Upper Mercer
Ore, Sand Block
Coal, Upper Mercer or No. 3a
Ore, Lower Mercer
Limestone, Lower Mercer
Ore, Boggs
Coal, Lower Mercer or No. 3
Coal, Vandusen
Ore, Lincoln
Coal, Bear Run
Coal, Quakertown or No. 2
Ore, Black Band
Ore, Guinea Fowl
Coal, Anthony
Clay, Sciotoville
Ore, Sharon
Coal, Sharon or No. 1
Conglomerate, Sharon
Ore, Harrison

Mississippian system
Limestone, local, Maxville

In drilling wells for oil and gas in Scioto County no carbonate rocks are encountered by the drill below the Maxville horizon until the Big Lime is reached. Along the Scioto Valley the top of the Big Lime is found at about sea level in eastern Morgan Township and at 170 feet below sea level at Portsmouth. Its position in the eastern part of the county is about 1,000 feet below sea level in southeastern Green, southeastern Vernon, and eastern Bloom townships.

Maxville Limestone

In Scioto County the Maxville limestone was largely removed by erosion before the deposition of the Pennsylvanian beds. Only a few scattered deposits of thin limestone have been found on the outcrop of the Maxville horizon. These are located near the top of the high hills and ridges in sections 3, 4, 22, and 26, Clay Township, and in sections 30 and 24, Harrison Township. The thickness of the limestone at these localities is generally less than 5 feet.

Records of wells drilled in eastern Scioto County generally make no mention of the Maxville and the limestone is, therefore, considered to be generally wanting below drainage in that area. On the Joseph Harper farm, however, in Section 32, Bloom Township, the Maxville limestone was penetrated by a well and a shaft many years ago. These explorations were located along the valley of Brushy Fork in the east part of Section 32, about one-eighth mile west of the Lawrence County line. A record of the well as recorded by W. C. Morse is as follows: [1]

		Thickness		Depth	
		Ft.	In.	Ft.	In.
Pennsylvanian system					
Allegheny series					
Surface		10	0	10	0
Sand rock		10	0	20	0
Black slate		1	0	21	0
Coal		-	4	21	4
Black slate		1	6	22	10
Grayish blue slate		12	0	34	10
Sand rock		1	0	35	10
Fire clay		6	9	42	7
Black slate		1	6	44	1
Gray slate		1	6	45	7
Fire clay		2	0	47	7
Black slate		1	0	48	7
Gray slate		2	0	50	7
Black slate		1	6	52	1
Diamond (?) coal		1	0	53	1
Sand rock		9	0	62	1
Black slate		4	0	66	1
Sand rock		31	0	97	1
Blue sand rock		4	0	101	1
Black slate		16	0	117	1
Coal, No. 2		1	0	118	1
Bedrock		6	0	124	1
Conglomerate rock		1	6	125	7
Bone shale		36	0	161	7
Green clay		1	6	163	1
Iron ore, Harrison		1	4	164	5
Mississippian system					
Limestone	Maxville	3	0	167	5
Green clay	Maxville	1	0	168	5
Limestone	Maxville	5	0	173	5
Dark sandy clay	Maxville	3	6	176	11
Limestone	Maxville	4	0	180	11
Clay	Maxville	-	6	181	5
Limestone	Maxville	15	0	196	5
Clay	Maxville	-	8	197	1
Limestone	Maxville	8	0	205	1
Clay	Maxville	-	6	205	7
Dark limestone	Maxville	1	0	206	7
Drill stopped	Maxville	-	-	206	7

[1] *Morse, W. C., The Maxwell limestone: Geol. Survey Ohio Bull. 13, p. 90, 1910.*

The body of Maxville limestone penetrated on the Harper farm is believed to cover a considerable area and to extend to the southeast in the direction of Olive Furnace. An analysis of a sample of the upper part of the Maxville limestone from the Harper shaft made a number of years ago is given below: [1]

Chemical analysis of the upper part of Maxville limestone from the Harper shaft, Section 32, Bloom Township, Scioto County, Paul Overmeyer, analyst

	Per cent
Iron, Fe	0.32
Silica, SiO_2	1.46
Phosphorus, P	0.014
Manganese, Mn	None
Alumina, Al_2O_3	0.64
Calcium oxide, CaO	54.28
Magnesia, MgO	0.44
Sulphur, S	0.06

Boggs Member

The Boggs member is generally wanting on the outcrop in Scioto County except over small areas in Bloom and Vernon townships where it is represented by an iron carbonate ore varying from a few inches to 6 feet in thickness and averaging about 2 feet. No limestone is found on the Boggs horizon in eastern Scioto County.

According to Stout [2] if all the lime and magnesia were combined as carbonates the results would be as follows:

	Per cent
Calcium carbonate	96.63
Magnesium carbonate	0.91
Total	97.54

Lower Mercer Limestone

Outcrops of Lower Mercer limestone in typical development are confined to the valley of Pine Creek south of Lyra in Vernon Township. In this area it is a hard blue definitely bedded limestone measuring a foot or so in thickness. Elsewhere on the outcrop in eastern Scioto County the position of the Lower Mercer limestone, though wanting, is closely marked by the Lower Mercer or Little Red Block ore.

Upper Mercer Limestone

The Upper Mercer limestone is rarely present on the outcrop in Scioto County but its position is closely marked by the persistent Upper Mercer ore. Where the limestone is present, it is generally less than 1 foot in thickness and is highly siliceous and impure yielding no economic possibilities worthy of mention.

Vanport Limestone

The Vanport limestone is confined in its distribution in Scioto County chiefly

[1] *Stout, Wilbur, Geology of southern Ohio: Geol. Survey Ohio Bull. 20, p. 480, 1916.*

[2] *Idem.*

to the main divides in eastern Bloom Township, to the ridges in eastern Vernon Township east of Pine Creek, and to the high hills lying to the north, east, and south of Ohio Furnace in eastern Green Township. The altitude of the member over this field varies in general from 800 to 900 feet. The limestone occurs in good development near Eifort in northeastern Bloom Township where it measures as much as 8 feet in thickness. Good bodies of Vanport limestone are also present in eastern Vernon Township but to the southwest the member becomes thin and patchy and near Ohio Furnace in Vernon Township it is represented by scattered lenses of flinty or cherty material. In this field the limestone is closely overlain and underlain by the Ferriferous ore and Clarion coal respectively. The Vanport has been quarried near Eifort and utilized for furnace flux and for road stone. For analyses of the Vanport limestone, see sections of this report dealing with the limestones in Lawrence County.

STARK COUNTY

General Considerations

Stark County having an area of about 579 square miles lies at the headwaters of the Tuscarawas drainage basin and along the southern boundary of the glacial drift sheet. The land surface is hilly to rolling with glacial drift deposits of variable thickness masking the old rock surface in all but the southeast part of the area. The bedrocks which occur above drainage range in age from Waverly to Conemaugh and have a total vertical thickness of approximately 600 feet. Outcrops of the lower part of this series, represented by the Waverly sandstones and shales, are confined to the Tuscarawas Valley in southeastern Jackson Township and through central Lawrence Township in the northwestern part. Scattered outcrops of beds above the Waverly throughout the glaciated area and in the unglaciated portion in the southern part represent members of Pottsville and Allegheny series of the Pennsylvanian. Beds of Conemaugh age are confined in their distribution for the most part to the high hills and ridges in Washington, Paris, and Osnaburg townships. The chief limestone members present in the Pennsylvanian strata outcropping in Stark County are, in descending order, as follows:

Upper Freeport limestone
Lower Freeport limestone
Hamden limestone
Vanport limestone
Putnam Hill limestone
Upper Mercer limestone
Lower Mercer limestone

The Maxville limestone is neither present on the outcrop nor has it been recognized in bore holes at any locality in Stark County. Wherever the complete stratigraphic succession of Mississippian strata is present, the Maxville is the top formation capping the sandstones and shales of the Waverly. Either this limestone was never laid down in the region of Stark County or it was deposited and later removed by erosion preceding the deposition of the Pennsylvanian sediments. Below the base of the coal-bearing series, shales and sandstones prevail for depths ranging from approximately 2,000 feet in northwestern Lawrence Township to about 2,800 feet in southeastern Paris Township. These shales are underlain by thick deposits of limestone and dolomite of Devonian and Silurian ages. In wells drilled for oil and gas the limestone is first encountered at depths below sea level ranging from about 1,250 feet in northwestern Lawrence Township to some 2,300 feet in southeastern Sandy Township and southeastern Paris Township.

Lower Mercer Limestone

The Lower Mercer limestone, the lowest persistent and well-defined limestone member of the Pottsville, is due above drainage along the larger valleys in Sugar Creek, Bethlehem, Pike, Canton, Tuscarawas, Perry, Lawrence, Jackson, and western Lake townships. Owing to widespread deposits of glacial drift, exposures of the member are not numerous. The limestone is typical in its lithologic characteristics in that it is a dark bluish gray dense-textured rock containing many fragments of fossils. The usual thickness is from 1 to 2 feet. The limestone has been utilized at a few scattered localities but its importance is overshadowed in this county by the thicker Putnam Hill member.

The Lower Mercer limestone with the overlying strata is well exposed in the pits of the National Fireproofing Company just south of Aultman in the southwest quarter of Section 30, Lake Township. Here the limestone was uncovered in securing clays and shales for the manufacture of conduit and hollow block. A description of the outcrops is as follows:

		Ft.	In.
Limestone, black, with flint nodules. Variable in thickness. Upper Mercer		2	6
Coal, bony, Bedford		1	1
Clay, gray, arenaceous		3	6
Shale, gray, arenaceous		18	0
Ore, carbonate form		--	2
Shale, soft, argillaceous		--	3
Limestone, bluish gray, hard, one layer	Lower Mercer	1	9
Shale, dark, calcareous	Lower Mercer	--	1
Limestone, impure	Lower Mercer	--	2
Shale, dark		--	6
Bottom of exposure.			

The 1-foot 9-inch bed of Lower Mercer limestone exposed at this locality was sampled by R. E. Lamborn on July 12, 1943, for chemical analysis.

Sample No. 401

Chemical analysis of the Lower Mercer limestone from pit of the National Fireproofing Corporation at Aultman, Section 3, Lake Township, Stark County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	1.63
Alumina, Al_2O_3	0.62
Ferric oxide, Fe_2O_3	0.15
Ferrous oxide, FeO	0.18
Iron disulphide, FeS_2	0.51
Magnesium oxide, MgO	0.72
Calcium oxide, CaO	51.81
Sodium oxide, Na_2O	0.08
Potassium oxide, K_2O	0.12
Water, hydroscopic, H_2O-	0.08
Water, combined, H_2O+	0.68
Carbon dioxide, CO_2	41.91
Titanium dioxide, TiO_2	0.02

Phosphorus pentoxide, P_2O_5	0.16
Sulphur trioxide, SO_3	0.14
Manganous oxide, MnO	0.12
Total	99.93

The per cent of each of the chief mineral components present in the sample as computed (Lamborn) from the chemical analysis is as follows:

Silica and hydrated aluminum silicates of sodium and potassium	3.11
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.18
Ferrous carbonate, $FeO. CO_2$	1.90
Iron disulphide, FeS_2	0.51
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO. P_2O_5$	0.35
Calcium sulphate, $CaO. SO_3$	0.24
Calcium carbonate, $CaO. CO_2$	91.96
Magnesium carbonate, $MgO. CO_2$	1.50
Manganese carbonate, $MnO. CO_2$	0.19
Water, hydroscopic, H_2O-	0.08
Unbalanced components (excess CO_2)	-0.11
Total	99.93

The Lower Mercer limestone is generally present near the crests of the high hills along the western edge of Lawrence Township at elevations of 1,100 feet or more. On the V. H. Oser property in the north central part of Section 18, this limestone has been quarried along the outcrop for road stone and possibly for agricultural purposes. At the best exposure observed at this locality the limestone consisted of a single bed 1 foot 8 inches in thickness. The underlying and overlying strata were covered with drift or surface deposits. A sample of the Lower Mercer at this locality was secured by R. E. Lamborn on July 15, 1943, for chemical analysis.

Sample No. 410

Chemical analysis of Lower Mercer limestone from outcrop on V. H. Oser property, Section 18, Lawrence Township, Stark County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	2.53
Alumina, Al_2O_3	0.79
Ferric oxide, Fe_2O_3	0.33
Ferrous oxide, FeO	1.17
Iron disulphide, FeS_2	0.07
Magnesium oxide, MgO	0.77
Calcium carbonate, CaO	51.70
Sodium oxide, Na_2O	0.05
Potassium oxide, K_2O	0.16
Water, hydroscopic, H_2O-	0.10
Water, combined, H_2O+	0.62
Calcium carbonate, $CaO. CO_2$	41.43
Titanium dioxide, TiO_2	0.04
Phosphorus pentoxide, P_2O_5	0.19
Sulphur trioxide, SO_3	0.09
Manganous oxide, MnO	0.07
Total	100.11

The per cent of each of the mineral constituents in Sample No. 410 as computed (Lamborn) from the chemical analysis, is stated below.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2, 2H_2O$	1.97
$Al_2O_3.2SiO_2.2H_2O$	0.06
Silica, SiO_2	1.60
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.39
Ferrous carbonate, $FeO.CO_2$	1.89
Iron disulphide, FeS_2	0.07
Titanium dioxide, TiO_2	0.04
Calcium phosphate, $3CaO.P_2O_5$	0.41
Calcium sulphate, $CaO.SO_3$	0.15
Calcium carbonate, $CaO.CO_2$	91.76
Magnesium carbonate, $MgO.CO_2$	1.61
Manganese carbonate, $MnO.CO_2$	0.11
Water, hydroscopic, H_2O-	0.10
Unbalanced components (excess CO_2, H_2O)	-0.05
Total	100.11

Upper Mercer Limestone

The Upper Mercer limestone member presents no unusual features in Stark County where it is in general a black impure siliceous limestone with nodules of black flint measuring from 1 to 2 feet in thickness and occurring at most exposures from 20 to 25 feet above the Lower Mercer limestone. For an analysis of the Upper Mercer limestone see pages of this report dealing with this member in Perry County.

Putnam Hill Limestone

The Putnam Hill or gray limestone ranks first in economic importance among the limestones outcropping in Stark County. This importance is due to its wide areal distribution in sufficient thickness to warrant small quarry operations along the outcrop, and to the generally high calcium and low magnesium content of the stone. The Putnam Hill reaches the surface over a broad belt extending through the central part of Stark County including parts of Sugar Creek, Bethlehem, Pike, Canton, Perry, Plain, Nimishillen, Lake, and Marlboro townships. Over this area the Putnam Hill is generally a bluish gray to brownish gray dense-textured hard compact limestone varying in thickness from 1 foot or less to a maximum of about 8 feet. Nodular flint which characterizes the Putnam Hill over parts of the field of outcrop in Ohio is generally wanting in Stark County. As sufficient data to construct a generalized rock column for the county is not available, the following section of outcrops near Howenstein, Pike Township, as described by Wilber Stout in 1919, is here given to show the stratigraphic relation of the Putnam Hill to other limestones previously described.

	Ft.	In.
Limestone, Putnam Hill	3	7
Shale	--	1
Coal, Brookville or No. 4	1	6
Clay, gray	6	0
Shale and covered	19	3
Shale	30	0
Ore, Upper Mercer	--	2
Limestone, dark, Upper Mercer	2	0
Coal, bony, Bedford	1	4
Clay, dark	1	4
Sandstone, clay bonded	1	6
Shale and sandstone	1	6
Shale, gray	19	4

Limestone, ferruginous	Lower Mercer	1	0
Limestone, gray		1	3
Clay, gray		2	0
Sandstone, clay bonded		3	0
Shale, dark		1	0

The Putnam Hill has been the source for many small limestone operations for many years in Stark County. It was formerly worked and calcined near Greentown, Lake Township, near Oval City, Plain Township, at Waco, Canton Township, near Richville, Perry Township, and near North Industry and Howenstein in Canton and Pike townships. Lime for agricultural use was the chief product of these operations. At Middlebranch, Plain Township, the Putnam Hill limestone has been utilized for 40 years by the Diamond Portland Cement Company for the manufacture of Portland cement. The Clapsadle Lime Company formerly quarried and calcined limestone in the southeast part of Section 24, Marlboro Township, and sold its product for utilization in the city disposal plant at Alliance. The limestone is reported to have a thickness of about 8 feet in this locality and it probably represents the Putnam Hill member.

The Putnam Hill limestone is quarried by the Greentown Lime Company in Section 29, Lake Township, where the stone is pulverized and marketed chiefly for agricultural purposes. The shale and glacial drift overlying the limestone are removed by stripping. A description of the rock exposures follows:

	Ft.	In.
Glacial drift	5	0
Shale, bluish gray	5	0
Limestone, bluish gray, dense-textured, Putnam Hill	4	9
Shale, black to bluish gray	--	2
Coal, soft, shaly, Brookville or No. 4	1	8
Clay, gray, plastic	3	6
Clay, arenaceous, somewhat ferruginous	5	0

The Putnam Hill limestone at this locality, having a thickness of 4 feet 9 inches, was sampled for chemical analysis on May 5, 1941, by R. E. Lamborn.

Sample No. 323

Chemical analysis of the Putnam Hill limestone from quarry of the Greentown Lime Company, near Greentown, Stark County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	3.35
Alumina, Al_2O_3	1.40
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.86
Iron disulphide, FeS_2	0.74
Magnesium oxide, MgO	1.08
Calcium oxide, CaO	50.28
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.04
Water, hydroscopic, H_2O-	0.14
Water, combined, H_2O+	0.41
Carbon dioxide, CO_2	41.10
Titanium dioxide, TiO_2	0.03

Phosphorus pentoxide, P_2O_5	0.12
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.15
Carbon, organic, C	0.22
Hydrogen, organic, H	0.02
Total	100.02

The per cent of each of the compounds probably present in Sample No. 323 has been computed (Lamborn) from the chemical analysis and is as follows:

Hydrated silicates $(Na, K)_2O.3\,Al_2O_3.6SiO_2.2H_2O$	0.58
Hydrated silicates $Al_2O_3.2SiO_2.2H_2O$	2.97
Silica, SiO_2	1.70
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.39
Iron disulphide, FeS_2	0.74
Titanium dioxide, TiO_2	0.03
Calcium phosphate, $3CaO.P_2O_5$	0.26
Calcium sulphate, $CaO.SO_3$	0.07
Calcium carbonate, $CaO.CO_2$	89.44
Magnesium carbonate, $MgO.CO_2$	2.26
Manganese carbonate, $MnO.CO_2$	0.24
Water hydroscopic, H_2O-	0.14
Organic matter	0.24
Unbalanced components (excess CO_2, H_2O)	-0.06
Total	100.02

The plant of the Diamond Portland Cement Company is located near Middlebranch in the northwest quarter of Section 1, Plain Township. For many years after the building of this plant early in the present century, Portland cement was produced from Putnam Hill limestone and shale immediately overlying it taken from a pit located just north of the plant. The present quarry is situated in the southwest part of Section 32, Marlboro Township, some two miles east of the old operations. The exposures in this quarry are described as follows:

	Ft.	In.
Glacial drift, removed by stripping	15	0
Limestone, generally bluish gray, layers somewhat platy with a thickness varying from 1 to 12 inches, Putnam Hill	8	7
Shale, black	--	3
Coal, bony, Brookville or No. 4	--	5
Clay, bluish gray, arenaceous, micaceous	2	6

A sample of the 8-foot 7-inch bed of limestone exposed in this quarry was secured for chemical analysis by R. E. Lamborn on May 8, 1941.

Sample No. 329

Chemical analysis of the Putnam Hill limestone from quarry of the Diamond Portland Cement Company, near Middlebranch, Stark County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	1.29
Alumina, Al_2O_3	0.49
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.71

Iron disulphide, FeS_2	0.08
Magnesium oxide, MgO	0.70
Calcium oxide, CaO	53.27
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	0.02
Water, hydroscopic, H_2O-	0.08
Water, combined, H_2O+	0.12
Carbon dioxide, CO_2	42.88
Titanium dioxide, TiO_2	0.02
Phosphorus pentoxide, P_2O_5	0.15
Sulphur trioxide, SO_3	0.02
Manganous oxide, MnO	0.10
Carbon, organic, C	0.09
Hydrogen, organic, H	--
Total	100.04

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.17
Hydrated silicates $Al_2O_3.2SiO_2.2H_2O$	1.08
Silica, SiO_2	0.71
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.14
Iron disulphide, FeS_2	0.08
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO.P_2O_5$	0.33
Calcium sulphate, $CaO.SO_3$	0.03
Calcium carbonate, $CaO.CO_2$	94.74
Magnesium carbonate, $MgO.CO_2$	1.47
Manganese carbonate, $MnO.CO_2$	0.16
Water, hydroscopic, H_2O-	0.08
Organic matter	0.09
Unbalanced components (excess CO_2, H_2O)	-0.08
Total	100.04

The Putnam Hill limestone is well exposed along a small tributary to Nimishillen Creek near the old abandoned mine in the northwest quarter of Section 35, Canton Township. South and southeast of this locality the Putnam Hill was formerly utilized for agricultural lime. A description of the exposures near the old mine is as follows:

		Ft.	In.
Limestone, bluish gray, one bed	Putnam Hill	1	11
Limestone, bluish gray, one bed	Putnam Hill	1	1
Shale, soft, bluish in color		--	4
Coal, bony	Brookville or No. 4	--	4
Coal, good	Brookville or No. 4	2	0
Shale parting	Brookville or No. 4	--	2
Coal	Brookville or No. 4	1	10

A sample of the Putnam Hill limestone collected at this locality by R. E. Lamborn on May 2, 1941, has a composition as given below.

Sample No. 334

Chemical analysis of a sample of Putnam Hill limestone taken from the outcrop in Section 35, Canton Township, Stark County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	3.97
Alumina, Al_2O_3	1.55
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.90
Iron disulphide, FeS_2	0.11
Magnesium oxide, MgO	1.19
Calcium oxide, CaO	49.97
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.01
Potassium oxide, K_2O	0.03
Water, hydroscopic, H_2O-	0.18
Water, combined, H_2O+	0.45
Carbon, dioxide, CO_2	40.96
Titanium dioxide, TiO_2	0.06
Phosphorus pentoxide, P_2O_5	0.15
Sulphur trioxide, SO_3	0.05
Manganous oxide, MnO	0.14
Carbon, organic, C	0.25
Hydrogen, organic, H	0.02
Total	100.01

The per cent of each of the mineral constituents in Sample No. 334 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_3O$	0.38
Silicates $Al_2O_3.2SiO_2.2H_2O$	3.55
Silica, SiO_2	2.15
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.45
Iron disulphide, FeS_2	0.11
Titanium dioxide, TiO_2	0.06
Calcium phosphate, $3CaO.P_2O_5$	0.33
Calcium sulphate, $CaO.SO_3$	0.09
Calcium carbonate, $CaO.CO_2$	88.80
Magnesium carbonate, $MgO.CO_2$	2.47
Manganese carbonate, $MnO.CO_2$	0.23
Water, hydroscopic, H_2O-	0.18
Organic matter	0.27
Unbalanced components (excess, CO_2, H_2O)	-0.08
Total	100.01

At the plant of the Sparta Ceramic Company located in the valley of Nimishillen Creek in the southeast part of Section 27, Pike Township, the Putnam Hill limestone is uncovered in securing materials for ceramic purposes. As the limestone has a high carbonate content it is pulverized and marketed for agricultural use. A measurement of the rock exposures is given below.

		Ft.	In.
Shale, bluish gray, somewhat arenaceous, estimated thickness		25	0
Limestone, light bluish gray, one layer	Putnam Hill	2	9

		Ft.	In.
Limestone, light bluish gray, one layer	Putnam Hill (cont.)	--	3
Shale, soft, dark, carbonaceous		--	3
Coal, Brookville or No. 4		1	2
Clay, plastic, somewhat mottled		3	0
Clay, bluish gray, somewhat arenaceous		4	4

The Putnam Hill limestone as described above was sampled at this locality on May 19, 1941, by R. E. Lamborn for chemical analysis.

Sample No. 331

Chemical analysis of the Putnam Hill limestone from pit of the Sparta Ceramic Company near East Sparta, Stark County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	2.07
Alumina, Al_2O_3	0.96
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.83
Iron disulphide, FeS_2	0.65
Magnesium oxide, MgO	1.16
Calcium oxide, CaO	51.51
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	<0.01
Potassium oxide, K_2O	0.02
Water, hydroscopic, H_2O-	0.16
Water, combined, H_2O+	0.27
Carbon dioxide, CO_2	42.10
Titanium dioxide, TiO_2	0.04
Phosphorus pentoxide, P_2O_5	0.16
Sulphur trioxide, SO_3	0.04
Manganous oxide, MnO	0.18
Carbon, organic, C	0.02
Hydrogen, organic, H	---
Total	100.19

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis with results as follows:

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.17
Hydrated silicates $Al_2O_3.2SiO_2.2H_2O$	2.27
Silica, SiO_2	0.94
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.34
Iron disulphide, FeS_2	0.65
Titanium dioxide, TiO_2	0.04
Calcium phosphate, $3CaO.P_2O_5$	0.35
Calcium sulphate, $CaO.SO_3$	0.06
Calcium carbonate, $CaO.CO_2$	91.55
Magnesium carbonate, $MgO.CO_2$	2.42
Manganese carbonate, $MnO.CO_2$	0.29
Water, hydroscopic, H_2O-	0.16
Organic matter	0.02
Unbalanced components (excess CO_2, H_2O)	-0.09
Total	100.19

The Putnam Hill limestone is generally well developed along Bear Run in Pike Township where it occurs above drainage as far north as the central part of Section 5. The limestone has been mined in a small way with the underlying Brookville coal by Clem Brown and Harry Shabot from a small opening on the Homer Bradley property in the north part of Section 8. Here the limestone is removed with the coal, is calcined using the coal for fuel, and the burned product is marketed as agricultural lime. The rock exposures at the mouth of the opening are described as follows:

		Ft.	In.
Shale, gray, arenaceous		8	0
Limestone, dark bluish gray, one layer	Putnam Hill	3	6
Limestone, dark bluish gray, one layer	Putnam Hill	--	6
Shale, dark, soft		--	5
Coal, weathered, Brookville or No. 4		2	6
Clay, gray		--	6

The 4 feet of limestone exposed here was sampled for chemical analysis on May 20, 1941, by R. E. Lamborn.

Sample No. 333

Chemical analysis of Putnam Hill limestone from mine on the Homer Bradley property, Section 8, Pike Township, Stark County, Downs Schaaf, analysts

	Per cent
Silica, SiO_2	3.68
Alumina, Al_2O_3	1.47
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	0.95
Iron disulphide, FeS_2	0.49
Magnesium oxide, MgO	1.04
Calcium oxide, CaO	50.14
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.03
Potassium oxide, K_2O	0.10
Water, hydroscopic, H_2O-	0.19
Water, combined, H_2O+	0.41
Carbon dioxide, CO_2	40.91
Titanium dioxide, TiO_2	0.06
Phosphorus pentoxide, P_2O_5	0.17
Sulphur trioxide, SO_3	0.07
Manganous oxide, MnO	0.12
Carbon, organic, C	0.22
Hydrogen, organic, H	0.02
Total	100.10

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Hydrated silicates	$(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.21
	$Al_2O_3.2SiO_2.2H_2O$	2.53
Silica, SiO_2		1.95
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$		0.04

Ferrous carbonate, $FeO.CO_2$	1.53
Iron disulphide, FeS_2	0.49
Titanium dioxide, TiO_2	0.06
Calcium phosphate, $3CaO.P_2O_5$	0.37
Calcium sulphate, $CaO.SO_3$	0.12
Calcium carbonate, $CaO.CO_2$	89.04
Magnesium carbonate, $MgO.CO_2$	2.17
Manganese carbonate, $MnO.CO_2$	0.19
Water, hydroscopic, H_2O-	0.19
Organic matter	0.24
Unbalanced components (excess CO_2, H_2O)	-0.03
Total	100.10

The Brookville or No. 4 Coal is mined by stripping (1941) along the sides of the hill located in the southeast quarter of Section 20, Bethlehem Township. The Putnam Hill limestone, which directly overlies the coal and which is wasted in the stripping process, is utilized by R. E. Zimmerman and Harold Zimmerman who pulverize the stone and market it for agriculture use. The rock exposures are described below.

		Ft.	In.
Shale, gray to light greenish		10	0
Shale, dark bluish gray, calcareous		7	6
Limestone, dark bluish gray, dense texture, one layer	Putnam Hill	2	8
Limestone, shaly	Putnam Hill	--	1
Coal, shaly, and black shale	Brookville or No. 4	--	4
Coal, not entire thickness	Brookville or No. 4	2	6

The 2-foot 8-inch block of Putnam Hill limestone was sampled for chemical analysis on April 29, 1941, by R. E. Lamborn. The composition is as follows:

Sample No. 319

Chemical analysis of the Putnam Hill limestone from pit of Zimmerman Brothers, near Navarre, Stark County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	4.86
Alumina, Al_2O_3	2.12
Ferric oxide, Fe_2O_3	0.07
Ferrous oxide, FeO	0.86
Iron disulphide, FeS_2	0.75
Magnesium oxide, MgO	1.10
Calcium oxide, CaO	48.50
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.03
Potassium oxide, K_2O	0.07
Water, hydroscopic, H_2O-	0.14
Water, combined, H_2O+	0.62
Carbon dioxide, CO_2	39.70
Titanium dioxide, TiO_2	0.09
Phosphorus pentoxide, P_2O_5	0.16

Sulphur trioxide, SO_3	0.08
Manganous oxide, MnO	0.20
Carbon, organic, C	0.50
Hydrogen, organic, H	0.04
Total	99.89

The per cent of each of the compounds probably present in Sample No. 319 has been computed (Lamborn) from the chemical analysis.

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.96
Hydrated silicates $Al_2O_3.2SiO_2.2H_2O$	4.41
Silica, SiO_2	2.36
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.08
Ferrous carbonate, $FeO.CO_2$	1.39
Iron disulphide, FeS_2	0.75
Titanium dioxide, TiO_2	0.09
Calcium phosphate, $3CaO.P_2O_5$	0.35
Calcium sulphate, $CaO.SO_3$	0.14
Calcium carbonate, $CaO.CO_2$	86.13
Magnesium carbonate, $MgO.CO_2$	2.30
Manganese carbonate, $MnO.CO_2$	0.32
Water, hydroscopic, H_2O-	0.14
Organic matter	0.54
Unbalanced components (excess CO_2, H_2O)	-0.07
Total	99.89

Vanport Limestone

In the southeastern or unglaciated portion of Stark County the horizon of the Vanport is generally occupied by sandstone and shale. In the glaciated part of this county the outcrops are so few in number and so restricted in vertical extent that little is definitely known concerning the occurrence and areal distribution of this member. Limestone believed to be Vanport in age was formerly quarried on the Allman property, Section 24, Bethlehem Township, where it was reported to have a thickness of about 6 feet. When visited by the writer in 1942 only about 1 1/2 feet of light gray somewhat shaly limestone was exposed at this locality. For analysis of the Vanport in a good state of development see pages of this report dealing with this limestone in Mahoning County.

Hamden Limestone

Hamden limestone is not conspicuously developed in Stark County. The Lower Kittanning coal is here generally closely overlain with dark shale which in places is fossiliferous.

Lower and Upper Freeport Limestones

The Lower and Upper Freeport limestones which occur close below the Lower and Upper Freeport coals respectively are generally more or less thin discontinuous nodular bodies embedded in the underclays of the coals. The horizons of these limestones are due to outcrops in Washington, Osnaburg, Paris, and Sandy townships. They are generally thin or wanting and, therefore, they have no appreciable economic importance in these areas.

SUMMIT COUNTY

General Considerations

The bedrocks which reach the surface in Summit County or are found immediately below the glacial drift consist in large part of sandstone, shale, and conglomerate with only a few thin beds of coal, clay, and limestone. The series exposed belong to the Devonian, Mississippian, and Pennsylvanian systems. Beds of Devonian age are represented by the Chagrin and Cleveland shales, outcrops of which are found along the Cuyahoga River Valley in western Northfield Township and in north central Boston Township. These shales are overlain by strata of Mississippian age which are likewise clastic in character and consist of shales with a few thin beds of sandstone. Their outcrops occur over an area of about 200 square miles bordering the Cuyahoga Valley through the central part of the area. The distribution of beds of Pottsville age, which contain two thin limestones of limited outcrops, are confined to the highlands in the eastern, western, and southern parts of the county. Outcrops are not plentiful in Summit County. The most continuous exposures are found along the larger valleys tributary to the Cuyahoga where stream erosion has degraded the channels through the glacial drift into the underlying bedrock. The total thickness of the bedrock series reaching the surface in Summit County is in excess of 800 feet. The succession, character, and thickness of the major groups exposed, gleaned in part from sections and descriptions by C. S. Prosser, [1] is essentially as given below. Field data at hand is not sufficient to detail the Pottsville series of this county into members.

Generalized Section of Bedrocks Outcropping in Summit County

	Feet
Pennsylvanian system	
Pottsville series	
Sandstone, conglomerate, shale, clay, coal, and limestone	275
Mississippian system	
Cuyahoga formation	
Shales, bluish gray, arenaceous, with one or more thin sandstone members	235 to 300
Sunbury formation	
Shale, dark, carbonaceous, soft to hard and fissile	10 to 15
Berea formation	
Sandstone, gray, fine-grained	16 to 47
Bedford formation	
Shale, generally bluish gray	42 to 60
Devonian system	
Ohio shale	
Shale. black, carbonaceous, fissile, Cleveland	7 to 16
Shale, bluish gray, arenaceous, Chagrin	175

[1] *Prosser, C. S., The Devonian and Mississippian formations of northeastern Ohio: Geol. Survey Ohio Bull. 15, pp. 143-180, 1912.*

The limestones which outcrops in Summit County are confined in vertical section to the Pottsville series and in horizontal distribution to the southeastern part of the county. The Maxville limestone which in normal succession occurs at the top of the Mississippian series in Ohio was removed by erosion in this section before deposition of Pennsylvanian sediments and is, therefore, wanting on the outcrop. The Pottsville limestones are represented by the Lower Mercer and Upper Mercer members scattered outcrops of which are expected in Springfield and Green townships. These limestones are generally thin and poorly exposed and they have not been utilized to any extent in Summit County.

Deep-seated Limestones

No limestones are encountered below drainage in Summit County until the top of the Big Lime series is reached. This series consists of thick beds of limestone and dolomite representing the Delaware and Columbus formations and the Monroe and Niagara groups. According to the records of oil and gas wells, the thickness of the Big Lime in Summit County varies from 1,350 feet to more than 1,650, being thinnest in the southwestern part and thickest in the northeastern portion. The upper surface of the Big Lime occurs at depths below sea level ranging from 700 feet in northwestern Richfield Township to about 1,500 feet in southeastern Green Township.

The plant of the Columbia Chemical Division of the Pittsburgh Plate Glass Company is located at Barberton in the southeast quarter of Norton Township. For many years limestone shipped to this plant from distant points has been calcined, the calcined stone hydrated, and the hydrated lime used in chemical processing. In order to secure a near-by supply of stone the company began in 1941 to sink two shafts to the Devonian limestone, which was reached at a depth of 2,197. The shafts are located south of the Erie Railroad and about 2 miles northwest of the plant.[1] Mining of limestone began in August 1942. The limestone which is mined has a vertical thickness of about 46 feet and, according to Dr. C. R. Stauffer,[2] comprises the top part of the Columbus formation. A log of the shaft, supplemented by core drilling in the vicinity to a depth of 2,851 feet, or 603 feet below the floor of the mine, has been prepared by Dr. Stauffer[3] and is essentially as given below.

The surface elevation at shaft No. 1 is 1,045 feet above tide.

	Thickness Ft.	Thickness In.	Total depth Ft.	Total depth In.
Pleistocene epoch				
Wisconsin glacial stage				
Drift, a sandy clay with gravel and a few boulders	20	0	20	0
Pennsylvanian system				
Sharon conglomerate				
Sandstone, buff, cross-bedded, coarse to medium, with bands of quartz pebbles and conglomerate	12	6	32	6
Sandstone, buff to gray, medium to fine	10	0	42	6
Sandstone, gray to buff, medium to fine, interbedded with arenaceous gray shale	13	4	55	10

[1] *Morrison, G. A., Mining a deep limestone deposit in Ohio: A.I.M.E. Tech. Pub. No. 1622, 1943.*

[2] *Stauffer, C. R., The geologic section at the limestone mine, Barberton, Ohio: Am. Jour. Sci., Vol. 242, p. 265, 1944.*

[3] *Op. Cit., pp. 254-259.*

Sandstone, gray to brown or buff, medium to coarse, with beds of quartz pebble conglomerate	9	0	64	10
Sandstone, gray to buff, coarse	10	0	74	10
Sandstone, gray, coarse to fine	10	0	84	10
Mississippian system				
Cuyahoga formation				
Sandstone, gray, fine-grained, with gray shale partings	10	0	94	10
Shale, argillaceous, gray, with bands of thin sandy layers	10	2	105	0
Shale, gray, banded, argillaceous	30	0	135	0
Sandstone, gray, fine-grained	10	0	145	0
Sandstone, gray, fine-grained, with interbedded gray shales	30	0	175	0
Shale, gray, argillaceous, with interbedded thin gray sandstone	5	0	180	0
Sandstone, gray, and interbedded gray shale	60	0	240	0
Sandstone, gray to gray-green	10	0	250	0
Shale, gray, argillaceous, banded	5	0	255	0
Shale, gray to gray-green, arenaceous, interbedded with fossiliferous sandstone	25	0	280	0
Shale, gray, banded, with sandstone layers and lenses	25	0	305	0
Shale, gray to gray green, interbedded with layers of gray sandstone, fossiliferous	10	0	315	0
Shale, gray to gray green, becoming dark bluish and with occasional thin cross-bedded sandstones	120	0	435	0
Sandstone, gray, fine-grained, with blue-gray shale partings	18	0	453	0
Shale, blue-gray to blue-black	50	0	503	0
Sunbury shale				
Shale, gray to dark gray, more or less brittle	3	0	506	0
Shale, dark gray to gray black, brittle. In the lower portion Lingula melie is common. Fish scales, conodonts (Prioniodus sp., etc) and Sporangites are also common. Sharp contact at the base where the Berea grit is absent	19	0	525	0
Bedford shale				
Sandstone, gray, fine-grained, shaly, oil-bearing	1	8	526	8
Shale, gray, soft at top, changing to dark gray with thin-bedded, fine-grained, gray sandstone interbedded	22	4	549	0
Shale, gray to gray-brown	31	0	580	0

Devonian system				
Cleveland shale				
Shale, black, slaty, with thin layers of sandstone	3	0	583	0
Shale, black to gray	57	0	640	0
Chagrin formation				
Shale, dark gray, with interbedded sandstones	10	0	650	0
Shale, gray, with interbedded gray sandstones	130	0	780	0
Shale, slaty, gray	60	0	840	0
Shale, gray, argillaceous, thick-bedded, with thin gray sandstones	35	0	875	0
Shale, gray, slaty	45	0	920	0
Shale, gray, argillaceous, soft	180	0	1100	0
Huron shale				
Shale, gray to chocolate brown; a 1/8 inch seam of gilsonite at base	130	0	1230	0
Shale, gray to black, banded	118	0	1348	0
Shale, brown to black, with gas	12	0	1360	0
Shale, gray to chocolate brown and black, with gas at base	115	0	1475	0
Shale, chocolate brown to black, with bands of gray	139	0	1614	0
Shale, chocolate brown to black, with rounded calcareous concretions 10 inches to 2 feet in diameter. Some have calcite veins	6	0	1620	0
Shale, gray to brown and black; a seam of gilsonite at the base	62	0	1682	0
Shale, blue gray, with crinoid stems and a 2 to 3-inch seam of gilsonite at the base	18	0	1700	0
Shale, gray to brown and black, banded. Gas at base	252	0	1952	0
Shale, gray to brown and black, banded. Scolecodonts and other poorly preserved fossils. Near the base plant fragments appear	100	0	2052	0
Shale, gray to brown, banded	37	0	2089	0
Hamilton (Olentangy) shale				
Shale, blue gray and gray brown, with pyrite concretions common. A 2-inch layer at the top is filled with pyritized fossils, such as *Tropidoleptus carinatus*, and *Athyris* sp., a large number of *Chonetes* sp., and a few ostracods such as *Hamiltonella* sp	17	0	2106	0
Shale, blue gray, with *Leiorhynchus multicosta* more or less common	27	0	2133	0

Shale, gray to bluish gray, calcareous, banded with brown or black. Sporangites sp. common in black bands. Leiorhynchus multicosta also occurs in these beds. A small quantity of gas given off at several horizons	37	0	2170	0
Shale, blue black to brown black, banded, brittle. Sporangites sp. and a few conodonts such as Lonchodina sp. found in these shaly beds	20	0	2190	0
Shale, brown-black, pyritiferous in the lower part. The following fossils are more or less common near the contact: Sporangites several species, fish teeth, scolecodonts, crinoid stems, Loxonema sp., Tentaculites gracillistriatus, Styliolina fissurella, and numerous conodonts such as: Angulodus sp., Bryantodus sp., Hindeodella sp., Hindeodelloides sp., Icriodus sp., Ligonodina sp., Metaprioniodus sp., Palmatolepis sp., Polygnathus sp., Synprioniodina sp., etc. Very sharp contact at base of black shale and gas encountered at that point	7	0	2197	0
Delaware limestone (Gas and some oil throughout)				
Limestone, gray, partly crystalline, with some cherty nodules. Among the fossils are Atrypa reticularis, Chonetes coronatus? Spirifer mucronatus? Spirifer sculptilis?, Spirifer (Paraspirifer) bownockeri, the latter occurring at the base	2	5	2199	5
Limestone, gray, partly crystalline, showing several styolitic bedding planes, a little chert and about a 2-inch shale parting at the base. Favosites turbinatus, Heliophyllum halli, Spirifer sp, Lumbriconereites sp., Atrypa reticularia, Eunicites sp., Nereidavus sp., etc., are found in these layers	2	7	2202	
Columbus (Onondaga) limestone				
Limestone, gray to light gray with several stylolitic seams or bedding planes conspicuous. A high grade limestone. Some of the common fossils are Atrypa reticularis, Spirifer duodenarius, and Stropheodonta inequiradiatus	2	5	2204	5
Flint or chert, a layer of light gray nodules	-	4	2204	9
Limestone, gray, partly crystalline, showing some good stylolite and containing Atrypa reticularis, Camarotoechia carolina, Stropheodonta demissa, Stropheodonta hemispherica, etc.	2	3	2207	0

Flint or chert, gray nodules with some limestone	-	8	2207	8
Limestone, gray, partly crystalline, with Atrypa reticularis, Camarotoechia sp., Chonetes hemisphericus, Schizophoria propinque, Spirifer duodenarius, Spirifer sp., Stropheodonta hemispherica, etc., and showing several seams of styolites	3	3	2210	11
Limestone, gray, with gray flint or chert nodules at the base	-	11	2211	10
Limestone, gray, partly crystalline, with Leptaena rhomboidalis and Stropheodonta inequiradiata	2	2	2214	0
Limestone, gray, with stylolitic seams and flint nodules	-	7	2214	7
Limestone, gray with stylolite and some gray flint in the lower part. Common fossils are Atrypa reticularis and Leptaena rhomboidalis	1	6	2216	1
Limestone, gray with flinty nodules in the lower part	5	0	2221	1
Limestone, gray, with stylolite seams Atrypa reticularis common. A gas pocket at top	1	6	2222	7
Limestone, gray, with a few small gray chert nodules, stylolites with several thin black line partings. Atrypa spinosa common. A prominent stylolite at the base	4	7	2227	2
Limestone, gray, partly crystalline, with fine line-like irregular partings near base	4	0	2231	2
Limestone, gray, partly crystalline, with a small amount of gray chert and several stylolitic seams. The fauna includes Proetus sp., Atrypa reticularis, and Spirifer gregarius, the latter especially abundant	5	0	2236	2
Limestone, gray to gray brown, showing stylolite. Spirifer sp. and other fossil fragments are common	5	1	2241	3
Limestone, gray, partly crystalline, contains Atrypa reticularis and shows a brown shaly parting at base.................................	1	10	2243	1
Limestone, gray to gray brown, with styolite and brown shale parting near bottom. Common fossils are Atrypa reticularis, Cyrtina hamiltonensis, Strophonella ampla together with various fragments of other fossils. This is the base of the high grade limestone and the bottom of the mine..............................	4	11	2248	0
Limestone, gray to dark gray, a siliceous limestone with 25% or more silica. Common fossils are Atrypa reticularis, Dalmanites				

aspectans, Stromatoporella sp, and various corals	3	3	2251	3
Limestone, siliceous, gray, irregularly banded with brown and showing stylolite. Common fossils are Atrypa reticularis, Cyrtina hamiltonensis, Rhipidomella vanuxemi, Spirifer sp., etc.	2	3	2253	6
Limestone, siliceous, gray to dark gray mottled. These beds contain corals and numerous other fossil fragments	61	6	2315	0
Limestone, siliceous, gray to dark gray, numerous crystals covered fossils and fossil fragments. Corals common	24	2	2339	2
Limestone, siliceous, gray to dark gray, with rough black partings between beds. Corals such as Diphyphyllum sp., Favosites sp., Zaphrentis sp., are numerous	25	0	2364	2
Limestone, very siliceous, dolomitic, gray with gray chert. Cup corals and other fossils common but not abundant	29	10	2394	0
Limestone, siliceous, dolomitic, gray, with an abundance of light gray chert. Various compound corals common but not abundant, one is probably a Michelinia sp.	23	0	2417	0
Lucas dolomite				
Limestone, dolomitic, gray, cherty, with a few corals and brachiopods. Much small fragmentary fossil material shown in the chert	34	0	2451	0
Limestone, dolomitic, gray, sandy. Bottom of very siliceous dolomitic limestone	2	0	2453	0
Sylvania sandstone				
Sandstone, gray to white. A little calcareous material in the lower part. Stylolite at the base and contact sharp	4	8	2457	8
Silurian system				
Bass Island dolomites (20 to 40% $MgCO_3$).				
Limestone, dolomitic, gray, with numerous small but conspicuous crystal faces showing. Sharp contact at the base. Fragments of fossils common	10	0	2467	8
Limestone, dolomitic, gray to dark gray, compact, stylolites common in upper part. No fossils observed	24	8	2492	4

Limestone, dolomitic, dark gray, compact. No fossils found................	2	8	2495	0
Limestone, dolomitic, dark gray, compact. No fossils observed. This extends to the bottom of the dolomitic limestone......................	25	0	2520	0
Dolomite, gray to dark gray, no fossils reported. (Analyses show over 40% $MgCO_3$)........................	31	0	2551	0
Salina formation				
Gypsum and gypsiferous shales. (Analyses show 50% $CaSO_4$)...............	200	0	2751	0
Salt with interbedded gray shale and shaly limestone..........................	100	0	2851	0

The character of the Columbus limestone, the top of which occurs in the shaft at a depth of 2,202 feet, is described by Stauffer [1] as follows:

"Beginning with the top of the mine and extending downward through about 220 feet are limestones of various degrees of purity which belong to the Columbus limestone. The 46 feet being mined is the upper part of that limestone and carries a fauna almost identical with that occurring in the limestone at the type section along the Scioto River at Columbus, Ohio. It is a gray to bluish gray partly crystalline limestone in medium to rather thick beds and having horizontal strings or layers of chert nodules at various horizons. These cherty layers are more abundant in the upper part of the mine although they influence the chemical composition of the rock throughout. Including the cherty layers the average is about 87 per cent $CaCO_3$ although when these are excluded the average rises to 94 per cent $CaCO_3$ or better. Below the mine floor the silica content of the limestone shows a marked increase."

The average composition of the Columbus limestone being mined as reported by Stauffer is indicated in the following table. [2]

Average composition of Columbus limestone from the shaft mine of the Columbia Chemical Division, Pittsburgh Plate Glass Company, Norton Township, Summit County

Depth from surface Ft.	Depth below shale contact Ft.	$CaCO_3$ Per cent	$MgCO_3$ Per cent	SiO_2 Per cent	R_2O_3 Per cent	Ignition loss Per cent
2202 to 2207	1 to 5	89.68	2.15	5.82	0.70	0.66
2207 to 2212	5 to 10	84.56	2.81	11.26	0.91	0.57
2212 to 2217	10 to 15	90.15	2.20	5.38	0.70	0.34
2217 to 2222	15 to 20	83.99	2.42	14.45	0.85	0.40
2222 to 2227	20 to 25	85.68	3.18	10.35	0.80	0.00
2227 to 2232	25 to 30	88.71	3.67	6.53	1.09	0.33
2232 to 2237	30 to 35	91.47	3.14	4.42	0.91	0.30
2237 to 2242	35 to 40	88.83	3.54	6.08	1.61	0.00
2242 to 2247	40 to 45	88.35	5.03	4.46	1.45	0.31
Average of 45 feet (computed)		87.935	3.056	7.639	1.002	0.323

The stone from the mine is utilized chiefly for the production of lime for chemical processing. The average stone analysis for the first six months of 1950

[1] *Stauffer, C. R., op. cit., p. 265.*

[2] *Stauffer, C. R., op. cit.*

supplied through the courtesy of Mr. S. Forbes, Plant Construction and Design Engineer at the mine, is as follows:

	Per cent
Calcium carbonate, $CaCO_3$	90.28
Magnesium carbonate, $MgCO_3$	4.32
Silica, SiO_2	5.00
R_2O_3	1.05

Lower and Upper Mercer Limestones

The Upper Mercer and Lower Mercer limestones are due to outcrop in the southeastern part of Summit County but the general presence of glacial drift permits few exposures. Each of these limestones is reported to have a thickness of 2 to 4 feet and to carry thin nodular iron ore on the upper surfaces. [1] Concerning their distribution in Summit County, Newberry [2] writes as follows:

"Near Magadore in Springfield Township the higher lands are found to be underlaid by a stratum of limestone, beneath which are usually a thin seam of coal and a thick stratum of fire clay; the latter supplying the material from which nearly all the stoneware of the county is manufactured. From 25 to 40 feet above the limestone to which I have referred is another which also overlies a coal seam. Both of these may be seen in Green Township between Greenburg and Greentown; and they may be traced thence, southerly through Stark, Tuscarawas, and Holmes counties and indeed nearly or quite to the Ohio River."

For analyses of Lower Mercer limestone see pages of this report dealing with that member in Stark County.

TRUMBULL COUNTY

General Considerations

The clastic varieties of the sedimentary series such as sandstones, shales, and conglomerates are the chief types reaching the surface or immediately underlying the glacial drift in Trumbull County. The age of the beds ranges from upper Devonian to Pottsville. The outcrops of the Devonian strata are confined to the valley of the Grand River in the northwestern part of the county whereas the Pottsville strata make up the higher hills and ridges in the southern part. The total thickness of the outcropping series is approximately 800 feet. No limestone beds of any economic importance outcrop in this county although a thin limestone bed of Pottsville age, probably the Lower Mercer limestone, has been reported as the highest outcropping member. [3] Below drainage the clastic character of the rocks comprising the series predominates until the Devonian limestones are reached at depths below sea level ranging from 1,000 feet in the northwestern part to 2,650 feet in the southeast corner of the county.

TUSCARAWAS COUNTY

General Considerations

Tuscarawas County embracing an area of about 572 square miles lies wholly within that part of the maturely dissected Allegheny Plateau the mantle rock of which is immediately underlain by strata of Pennsylvanian age. The land surface

[1] *Newberry, J. S., Geology of Summit County: Geol. Survey Ohio Vol. I, Pt. I, P. 220, 1873.*

[2] *Op. cit., p. 218.*

[3] *Read, M. C., Geology of Trumbull County: Geol. Survey Ohio Vol. I, Pt. I, p. 495, 1873.*

in this county is, in general, rough and rugged for the hilltops rise to heights of 200 to 300 feet above the bottoms of the larger valleys. Glacial drift deposits are generally wanting except over a small area in the northwest corner. Glacial outwash, however, is a conspicuous element in the unconsolidated materials. It is represented by terrace and flood plain deposits along the Tuscarawas Valley and along the major southern-sloping tributary valleys such as Sugar Creek and Big Sandy. The bedrocks which reach the surface in Tuscarawas County and are exposed at many places represent members of the Pottsville, Allegheny, and Conemaugh series of the Pennsylvanian system and have a total vertical thickness of about 720 feet. As this area extends across the crest of the Cambridge Arch and lies just east of the high structural ridge which forms its western edge, the general direction of dip of the beds in this county is to the southeast. The regularity of the dip, however, is broken by the presence of many structural noses, depressions, and terrace-like features. As a result of the regional dip modified by small structural irregularity and of the hilly condition of the land surface, the outcrops of the Pottsville series are confined to the northwestern corner and to deep valleys in northwestern half of the county whereas the strata of Conemaugh age comprise the high hills and ridges in the southern and southeastern parts. A generalized section of the rocks exposed in Tuscarawas County prepared from field notes and sections by R. E. Lamborn is as follows:

Generalized Section of Bedrocks Exposed in Tuscarawas County

	Ft.	In.
Pennsylvanian system		
Conemaugh series		
Sandstone, discontinuous, and sandy shales, Morgantown sandstone horizon	100	0
Limestone, greenish gray, crystalline, discontinuous, Ames	1	6
Shale, bluish gray, olive to red	46	0
Coal, shaly, local, Barton	1	0
Clay, calcareous, with limestone nodules, Ewing limestone horizon	8	0
Shale, bluish gray, sandy	35	10
Coal, shaly, Anderson	--	6
Clay, yellowish gray	4	0
Shale, bluish gray to pink, variegated	19	4
Limestone, nodular, ferruginous, fossiliferous, discontinuous, Cambridge	--	5
Shale, dark bluish gray	5	0
Coal, shaly, local, Wilgus	--	6
Clay, dark bluish gray, calcareous	5	2
Sandstone, local, and arenaceous shale, Buffalo sandstone horizon	23	1
Shale, dark, carbonaceous, arenaceous, Brush Creek	4	0
Coal, generally wanting, Brush Creek	--	--
Clay, dark bluish gray, discontinuous	2	6
Shale, bluish gray	13	2
Coal and black shale, Mason	1	0
Clay, bluish gray to variegated	5	6
Sandstone, local, and sandy shales, Upper Mahoning sandstone horizon	32	0
Coal, discontinuous, Mahoning	1	9
Clay, bluish gray, calcareous	5	8
Sandstone, thin-bedded to massive, and sandy shales, Lower Mahoning sandstone horizon	27	9
Shale, carbonaceous, with some iron ore nodules	5	0

Allegheny series		
Coal, Upper Freeport or No. 7	2	2
Clay, bluish gray, calcareous	6	0
Shale, bluish gray	4	0
Clay, light bluish gray, plastic and flint, local, Bolivar	7	6
Sandstone, local, and sandy shales, Upper Freeport sandstone horizon	21	6
Coal, generally shaly, Lower Freeport or No. 6a	1	3
Clay, bluish gray, calcareous	2	0
Limestone, locally present, Lower Freeport	--	6
Clay, bluish gray, calcareous	2	8
Sandstone, local, and sandy shales, Upper Freeport sandstone horizon	63	7
Black shale and shaly coal (Middle Kittanning or No. 6)	--	6 1/2
Coal, good (Middle Kittanning or No. 6)	2	2
Parting (Middle Kittanning or No. 6)	--	1
Coal, good (Middle Kittanning or No. 6)	--	11
Clay, bluish gray	4	4
Shale, bluish gray, arenaceous	15	0
Coal, local, Strasburg	--	10
Clay, shaly, impure, Oak Hill	3	0
Shale, dark, with iron carbonate nodules	15	7
Limestone, dark, nodular, ferruginous, locally present, Hamden	--	3
Shale, soft, dark, fossiliferous	--	6
Coal, Lower Kittanning or No. 5	2	6
Clay, bluish gray, flint and plastic	8	2
Shale, bluish gray, arenaceous	14	6
Limestone, bluish gray, fossiliferous, local, Vanport	3	0
Shale, bluish gray, arenaceous	27	11
Limestone, light bluish gray, dense, fossiliferous, Putnam Hill	1	0
Shale, dark, carbonaceous, discontinuous	--	5
Coal, often shaly, Brookville or No. 4	1	7
Pottsville series		
Clay, gray, plastic	5	0
Clay, gray, arenaceous, local, Tionesta	4	0
Shale, bluish gray, sandy, and shaly sandstone	39	0
Limestone, black, flinty, Upper Mercer	--	6
Coal and black shale, Bedford	--	9
Clay, bluish gray	3	0
Shale and sandstone	12	4
Coal, locally present, Upper Mercer or No. 3a	1	0
Clay, bluish gray	1	0
Shale, bluish gray, fossiliferous, sandy	12	0
Limestone, bluish gray, fossiliferous, Lower Mercer	2	6
Coal, shaly, and black shale, local, Middle Mercer	--	4
Clay, bluish gray	4	9
Coal, shaly, and black shale, locally present, Flint Ridge	--	4
Clay, bluish gray	7	2

Shale, bluish gray, arenaceous	25	0
Sandstone, heavy-bedded, Massillon	40	0

Tuscarawas County has yielded large quantities of clay for the production of clay products and a large tonnage of coal for both railroad shipment and for local domestic and industrial consumption but it is not outstanding for its limestone resources. As indicated in the general section, ten limestone members have been recognized on the outcrop. Of these the Lower Mercer, Upper Mercer, Putnam Hill, and Vanport lead in importance owing to their thicker development in some areas and greater purity. Each of these members has been utilized from time to time for local economic needs. The Hamden, Lower Freeport, Brush Creek, Cambridge, Ewing, and Ames are generally too thin or too impure to merit more than passing notice.

The bedrocks occurring below drainage in Tuscarawas County consist of sandstones and shales to depths of many hundreds of feet. In wells drilled for oil and gas no limestones are encountered below the Pottsville until the Middle Devonian beds are reached at depths below sea level ranging from 1,500 feet in the northwest corner of the county to 2,500 feet in the southeast corner.

Lower Mercer Limestone

The Lower Mercer limestone, the lowest limestone of the Pottsville outcropping in Tuscarawas County, occurs near water level along the Tuscarawas River at Newcomerstown. It is generally present close above drainage along the valley of Evans Creek in the southeast part of Bucks Township and along the deeper valleys in Wayne, Franklin, Lawrence, and Dover townships. The limestone is typical in its development in this county as it is a dark bluish gray, dense-textured, hard limestone which occurs either as a single layer or as two or three layers separated by bedding planes only. The thickness of the limestone on the outcrop varies from a few inches to as much as 3 feet 3 inches but averages a little more than 2 feet. The Lower Mercer was formerly quarried in a small way near Zoar in Lawrence Township and was calcined and sold for agricultural lime. It was likewise formerly quarried near the old salt works just west of Dover and was utilized for furnace flux.[1] For analyses of Lower Mercer limestone see pages of this report dealing with that member in Coshocton County.

Upper Mercer Limestone

The areal distribution of outcrops of Upper Mercer limestone in Tuscarawas County is somewhat greater than that of the Lower Mercer as the former occurs on an average about 30 feet higher in the section. Outcrops of this member have been identified in Bucks, Sugar Creek, Wayne, Dover, Franklin, and Lawrence townships. Where present the Upper Mercer is generally a hard, black, dense-textured flinty impure limestone less than 1 foot in thickness. Locally, however, the member is much better developed than the average and the limestone is less impure. One such occurrence is located at Zoar in eastern Lawrence Township where the Upper Mercer was formerly quarried, calcined, and sold for agricultural lime by the Zoar Agricultural Lime Company. The operations had been abandoned when Zoar was visited by the writer in 1942. A sample from the 4-foot bed of Upper Mercer limestone at this locality, however, was secured by E. J. Bognar in 1926 and was analyzed by D. J. Demorest for the Geological Survey.

Sample No. 1010

Chemical analysis of Upper Mercer limestone from quarry of the Zoar

[1] *Orton, Edward, Geological Survey Ohio Vol. V., p. 260, 1884.*

Agricultural Lime Company, Lawrence Township, Tuscarawas County, D. J. Demorest, analyst

	Per cent
Moisture, at 105°C	0.12
Silica, SiO_2	1.70
Alumina, Al_2O_3	0.36
Ferric oxide, Fe_2O_3	1.74
Phosphorus pentoxide, P_2O_5	0.25
Titanium dioxide, TiO_2	0.03
Calcium carbonate, $CaO.CO_2$	92.75
Magnesium carbonate, $MgO.CO_2$	1.51
Sulphur, S	0.18
Total	98.64

Putnam Hill Limestone

The horizon of the Putnam Hill limestone reaches the surface over a large area in Tuscarawas County. Outcrops of this member have been recognized in every township lying west of a diagonal line extending through Mineral City, New Philadelphia, and Port Washington, and then south to the southern boundary of the county. Over this field of outcrops the Putnam Hill is generally typical in its lithologic character but it is usually thin. Nodules of chert are found in places embedded in the limestone but such developments are local in character. Measurements of the limestone on the outcrop show variations in thickness ranging from 4 inches to 2 feet 6 inches but an average of 20 determinations is about 1 foot. In Tuscarawas County the Putnam Hill limestone is best developed in western Sandy and northern Lawrence townships where it measures 2 feet or more in thickness.

The Putnam Hill limestone has been little utilized in Tuscarawas County and, due to its general thin development, its presence adds little to the potential mineral resources of the area. It was formerly quarried on a small scale for local use in the northwest corner of Lawrence Township and also at a locality situated about 1 1/2 miles south of west of Mineral City in southern Sandy Township. A sample taken by E. J. Bognar in 1926 at the place last mentioned was analyzed by D. J. Demorest for the Survey with the following results:

Sample No. 1011

Chemical analysis of Putnam Hill limestone from quarry located 1 1/2 miles south of west of Mineral City, Sandy Township, Tuscarawas County, D. J. Demorest, analyst

	Per cent
Silica, SiO_2	9.71
Alumina, Al_2O_3	0.68
Ferric oxide, Fe_2O_3	2.09
Calcium carbonate, $CaO.CO_2$	84.41
Magnesium carbonate, $MgO.CO_2$	1.19
Titanium dioxide, TiO_2	0.09
Phosphorus pentoxide, P_2O_5	0.14
Sulphur, S	0.09
Moisture, at 105°C	0.32
Total	98.72

Vanport Limestone

The Vanport limestone in Tuscarawas County is confined in its occurrence on the outcrop to a few scattered areas in Bucks, Auburn, Sugar Creek, and Dover townships. At other localities where it is due in this county the horizon of the Vanport is occupied with calcareous and arenaceous shales. Where it occurs in typical development the Vanport is a gray to light bluish gray rather dense-textured fossiliferous limestone which, in general, is a little lighter colored than the Putnam Hill. In places the top part of the member is more or less ferruginous. On fresh exposure the limestone appears heavy bedded and massive but on weathering it tends to split up into thin somewhat nodular layers varying in thickness from 1 to 3 inches. Variations in development of the Vanport limestone in this county range from a few inches to 6 feet 2 inches. The member is generally underlain and overlain with shale. Its stratigraphic position in this county is on an average about 28 feet above the Putnam Hill limestone and about 23 feet below the Lower Kittanning coal.

A small body of Vanport limestone outcrops at an elevation of about 1,000 feet in Dover Township some 2 1/2 miles north of Dover. This limestone was being worked in a small way in 1941 by L. H. Renner & Sons in a quarry located about three-eighths of a mile southwest of Oak Grove school. Here the limestone is calcined and marketed for agricultural use. A measurement of the rock exposures in this vicinity is given below:

		Ft.	In.
Shale, black, carbonaceous		--	6
Coal	Lower Kittanning or No. 5	--	6
Shale, parting	Lower Kittanning or No. 5	--	1
Coal	Lower Kittanning or No. 5	2	6
Clay, gray, plastic		1	0
Covered interval		13	0
Limestone, dark bluish gray, arenaceous, fossiliferous, Vanport		3	8

A sample of the Vanport limestone was secured from this quarry by R. E. Lamborn on April 28, 1941, for chemical analysis.

Sample No. 318

Chemical analysis of Vanport limestone from quarry of L. H. Renner Sons, near Oak Grove School, Dover Township, Tuscarawas County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	3.62
Alumina, Al_2O_3	1.25
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	0.98
Iron disulphide, FeS_2	0.04
Magnesium oxide, MgO	0.63
Calcium oxide, CaO	51.12
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.05
Water, hydroscopic, H_2O-	0.11
Water, combined, H_2O+	0.38
Carbon dioxide, CO_2	41.30
Titanium dioxide, TiO_2	0.09
Phosphorus pentoxide, P_2O_5	0.18
Sulphur trioxide, SO_3	0.08
Manganous oxide, MnO	0.20

Carbon, organic, C	0.06
Hydrogen, organic, H	----
Total	100.14

The per cent of each of the compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.67
Silicates $Al_2O_3.2SiO_2.2H_2O$	2.50
Silica, SiO_2	2.15
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	1.58
Iron disulphide, FeS_2	0.04
Titanium dioxide, TiO_2	0.09
Calcium phosphate, $3CaO.P_2O_5$	0.39
Calcium sulphate, $CaO.SO_3$	0.13
Calcium carbonate, $CaO.CO_2$	90.76
Magnesium carbonate, $MgO.CO_2$	1.32
Manganese carbonate, $MnO.CO_2$	0.32
Water, hydroscopic, H_2O-	0.11
Organic matter	0.06
Unbalanced components (excess CO_2, H_2O)	-0.02
Total	100.14

The Vanport limestone is present in good development over small areas in the south central part of Sugar Creek Township and the north central part of Auburn Township. It has been worked on a small scale for agricultural lime in the southwest quarter of Section 6, Sugar Creek Township, where the stone is of good purity and where it has a thickness of about 6 feet. It likewise occurs in good development near the crest of the high ridge in the southeast quarter of Section 9, also in Sugar Creek Township. Here the Vanport was being quarried (1941) on the property of A. J. Slabach for agricultural lime. A description of the rock exposures at this locality is as follows:

	Ft.	In.
Shale	8	0
Limestone, bluish gray, dense, in nodular layers, 1 to 3 inches in thickness, Vanport	6	2
Covered interval	19	0
Limestone, bluish gray, Putnam Hill	1	0
Coal, Brookville or No. 4	1	7
Clay and covered	6	0

The 6-foot 2-inch bed of Vanport limestone exposed in the Slabach quarry and described above was sampled by R. E. Lamborn on April 29, 1941, for chemical analysis.

Sample No. 320

Chemical analysis of Vanport limestone from quarry of A. J. Slabach, Section 9, Sugar Creek Township, Tuscarawas County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	6.77
Alumina, Al_2O_3	1.28
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO	0.74
Iron disulphide, FeS_2	0.05
Magnesium oxide, MgO	0.60

Calcium oxide, CaO	49.63
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.05
Water, hydroscopic, H_2O-	0.12
Water, combined, H_2O+	0.40
Carbon dioxide, CO_2	39.95
Titanium dioxide, TiO_2	0.08
Phosphorus pentoxide, P_2O_5	0.15
Sulphur trioxide, SO_3	0.08
Manganous oxide, MnO	0.16
Carbon, organic, C	0.02
Hydrogen, organic, H	---
Total	100.12

The per cent of each of the compounds probably present in Sample No. 320 has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.67
Silicates $Al_2O_3.2SiO_2.2H_2O$	2.58
Silica, SiO_2	5.26
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.19
Iron disulphide, FeS_2	0.05
Titanium dioxide, TiO_2	0.08
Calcium phosphate, $3CaO.P_2O_5$	0.33
Calcium sulphate, $CaO.SO_3$	0.14
Calcium carbonate, $CaO.CO_2$	88.16
Magnesium carbonate, $MgO.CO_2$	1.25
Manganese carbonate, $MnO.CO_2$	0.26
Water, hydroscopic, H_2O-	0.12
Organic matter	0.02
Unbalanced components (excess $CO_2.H_2O$)	-0.01
Total	100.12

The known deposits of Vanport limestone in Bucks Township are confined to the southeastern part where the limestone has good purity but is invariably thin on the outcrop. In the north central part of Section 19, the limestone measures 3 feet where it outcrops at an elevation of 1,043 feet. In the south central part of Section 11, the Vanport has been quarried in a small way on the Harry R. King property. Here it is crushed to the necessary fineness and marketed as raw limestone for agricultural use. A description of the outcrops is given below:

	Ft.	In.
Shale, dark	2	0
Coal, Middle Kittanning	1	3
Covered interval	23	6
Coal, reported thickness, Lower Kittanning	1	6
Covered interval	7	9
Shale, bluish gray	15	0
Limestone, gray, dense-textured, fossiliferous, Vanport	2	6

The Vanport limestone in the King quarry as described above was sampled for chemical analysis on April 28, 1941, by R. E. Lamborn. The composition of the sample expressed in the oxide form is given below:

Sample No. 317

Chemical analysis of Vanport limestone from quarry of H. R. King, Section 11, Bucks Township, Tuscarawas County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	2.41
Alumina, Al_2O_3	0.74
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	0.70
Iron disulphide, FeS_2	0.02
Magnesium oxide, MgO	0.55
Calcium oxide, CaO	52.50
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.04
Water, hydroscopic, H_2O-	0.06
Water, combined, H_2O+	0.21
Carbon dioxide, CO_2	42.12
Titanium dioxide, TiO_2	0.08
Phosphorus pentoxide, P_2O_5	0.21
Sulphur trioxide, SO_3	0.18
Manganous oxide, MnO	0.25
Carbon, organic, C	0.01
Hydrogen, organic, H	--
Total	100.13

The per cent of each of the mineral compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.58
Silicates $Al_2O_3.2SiO_2.2H_2O$	1.29
Silica, SiO_2	1.53
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	1.13
Iron disulphide, FeS_2	0.02
Titanium dioxide, TiO_2	0.08
Calcium phosphate, $3CaO.P_2O_5$	0.46
Calcium sulphate, $CaO.SO_3$	0.31
Calcium carbonate, $CaO.CO_2$	93.03
Magnesium carbonate, $MgO.CO_2$	1.15
Manganese carbonate, $MnO.CO_2$	0.41
Water, hydroscopic, H_2O-	0.06
Organic matter	0.01
Unbalanced components (deficiency CO_2, H_2O)	+0.03
Total	100.13

Hamden Member

The Hamden limestone is present at only a few localities in Tuscarawas County where it is represented by a thin bed of carbonaceous ferruginous limestone varying from a few inches to 1 foot in thickness and occurring from 1 to 3 feet above the Lower Kittanning coal. In the absence of the limestone, the horizon is often marked by dark fossiliferous shale.

Lower Freeport Limestone

The Lower Freeport limestone is generally wanting in this county. Its known occurrence on the outcrop is limited to a few localities in Clay Township where it is either thin or nodular in character. The Upper Freeport and Mahoning limestones, which closely resemble the Lower Freeport in lithologic character, have not been positively identified in this county.

Brush Creek Member

The Brush Creek member in Tuscarawas County is composed in large part of sandy carbonaceous shale with only trifling amounts of limestone. For analysis of the Brush Creek limestone in its best field of development in Ohio see pages of this report dealing with the member in Gallia and Lawrence counties.

Cambridge Limestone

In Perry and Washington townships where the Cambridge reaches its best development on the outcrop in this county the limestone measures only a few inches in thickness and is generally highly ferruginous and impure.

Ewing Limestone

No economic importance can be attached to the Ewing member for it consists in this county of only scattered nodules of limestone embedded in calcareous clays underlying the Barton coal. Outcrops are confined for the most part to Perry and Washington townships.

Ames Limestone

Outcrops of the Ames limestone are confined to the summits of the high hills and ridges in Perry and Washington townships. The limestone is typical in lithologic character and varies from a few inches to 4 feet in thickness. For composition of the Ames limestone see Samples No. 360, 361, and 362.

VINTON COUNTY [1]

General Considerations

Vinton County, embracing an area of about 422 square miles, contains within its boundaries outcrops of bedrocks representing that part of the section extending from the Cuyahoga shales of Mississippian age to the Cambridge limestone of the Conemaugh series of Pennsylvanian age. The total vertical thickness of the strata outcropping in this county is approximately 950 feet. In areal distribution the exposures of the Mississippian beds consisting of sandstone, conglomerates, and shales are restricted to the western part of the county including all or parts of Harrison, Eagle, Richland, and Jackson townships. Owing to the regional slope of the rock formations to the eastward, the Mississippian series pass in that direction beneath the younger and overlying strata of Pennsylvanian age which comprise the surface bedrocks in the eastern four-fifths of the county. The limestone members

[1] *For a detailed account of the geology of Vinton County see Geol. Survey Ohio Bull. 31, 1927, by Wilber Stout, from which much information concerning the limestones in this county has been secured.*

which reach the surface are found entirely in the Pennsylvanian or coal-bearing series. Their relation to closely associated beds is shown in the generalized section.

Generalized Section of Bedrocks Outcropping in Vinton County

	Ft.	In.
Pennsylvanian system		
Conemaugh series		
Limestone, gray, fossiliferous, Cambridge	--	8
Shale, gray	2	0
Coal, impure, locally present, Wilgus	--	6
Clay and clay shale	10	6
Sandstone, locally conglomeratic, locally wanting, Buffalo	15	0
Shale, gray	3	0
Limestone or flint, fossiliferous (Brush Creek)	2	0
Shales, part calcareous, with a few fossils (Brush Creek)	27	1
Limestone or shale, very fossiliferous (Brush Creek)	--	11
Shales, clay shales, and sandstones	23	4
Coal, impure, Mason	1	2
Clay, light, plastic, impure	4	6
Sandstone, locally present, Upper Mahoning	14	5
Coal, very unsteady, Mahoning	--	3
Clay, plastic, light to mottled, impure	5	0
Limestone, light, nodular, only locally present, Mahoning	-	6
Sandstone, often replaced by shale, Lower Mahoning	21	6
Allegheny series		
Coal, generally thin, often wanting, Upper Freeport or No. 7	1	0
Clay, plastic, impure	5	0
Shale, gray	2	6
Limestone, nodular, fresh water, Upper Freeport	--	5
Coal, everywhere thin, often wanting	--	1
Clay, flint and plastic	6	0
Shale, gray	9	9
Sandstone, largely replaced by shale, Upper Freeport	18	0
Coal, only occasionally present, Lower Freeport or No. 6a	--	3
Clay, plastic, impure	6	0
Shale, gray, siliceous	12	0
Limestone, nodular, Lower Freeport	--	6
Sandstone, often replaced by shale, Lower Freeport	30	0
Shale, gray, siliceous	5	0
Coal, persistent, Middle Kittanning or No. 6	2	6
Clay, shaly, impure	2	0
Shale and sandstone	22	0
Coal, thin, local, Strasburg	--	2

Clay, flint and plastic, Oak Hill	4	0
Iron ore, very local, Hamden	3	0
Shale, gray, siliceous	5	2
Coal, persistent, Lower Kittanning or No. 5	1	10
Clay, plastic, fair quality	7	0
Shale and sandstone	22	6
Ore, locally present, Ferriferous	--	5
Limestone, gray, fossiliferous, Vanport	4	7
Shale, dark, carbonaceous	2	2
Coal, locally present, Scrubgrass	--	11
Shale, black, carbonaceous	4	9
Coal, persistent, Clarion or No. 4a	3	2
Clay, flint and plastic	6	0
Sandstone, locally well developed, Clarion	10	0
Shale, gray, siliceous	4	0
Coal, locally with good thickness, Winters	2	3
Clay, plastic, good quality	3	7
Flint, gray to black, calcareous, Zaleski	1	2
Shale, dark, siliceous	1	0
Coal, thin, local, Ogan	--	10
Clay, plastic, fair purity	2	8
Shale and sandstone	16	4
Limestone and calcareous shale, Putnam Hill	2	9
Coal, Brookville or No. 4	2	5
Pottsville series		
Clay, plastic	4	6
Shale, gray, siliceous	2	6
Coal, thin, often wanting, Tionesta or 3b	--	3
Clay, plastic, locally present	1	6
Shale and sandstone	19	2
Ore, moderately persistent	--	4
Limestone or flint, seldom present, Upper Mercer	--	3
Shale, dark, carbonaceous	--	9
Coal, locally present	--	3
Clay, plastic, siliceous	--	10
Shale and sandstone	8	11
Ore, generally absent	--	3
Shale and sandstone	3	8
Coal, thin, shaly, Upper Mercer or No. 3a	--	8
Clay, plastic, siliceous	2	3
Shale and sandstone	15	9
Ore, local	--	3
Shale, gray, siliceous	2	10
Shale, calcareous, fossiliferous } Lower Mercer	2	7
Limestone, hard, gray } Lower Mercer	--	7
Shale, dark, carbonaceous	--	6
Coal, thin, generally present	--	5
Clay, plastic, siliceous	3	6
Shale and sandstone	6	3
Coal, moderately steady, Flint Ridge	--	6
Clay, plastic, siliceous	3	0
Shale and sandstone	10	11

Ore, locally developed, Boggs	--	3
Shale, gray	1	6
Coal, fairly persistent, Lower Mercer or No. 3	1	6
Clay, plastic, siliceous	3	0
Sandstone, often replaced by shale, Upper Massillon	53	8
Coal, unsteady, Bear Run	--	10
Clay, plastic, impure	2	0
Shale and sandstone	8	0
Coal, moderately persistent, Quakertown, No. 2	2	2
Clay, plastic, siliceous	2	6
Shale and sandstone	25	0
Coal, thin, local, Huckleberry	--	2
Clay, plastic, impure	2	0
Shale, gray, siliceous	2	0
Coal, very local, Anthony	--	4
Clay, flint and plastic, Sciotoville	5	0
Shale and sandstone	14	6
Coal, very local, Sharon	--	6
Clay, impure	1	0
Conglomerate, very local, Sharon	5	0
Iron ore, irregular, local, Harrison	--	6

Mississippian system

Logan formation

Sandstones, fine-grained, bluish gray, and sandy shales, Vinton member	0 to 90 feet
Sandstone, coarse-grained, thin-bedded, interbedded with fine-grained sandstone, Allensville member	12 to 15
Sandstone, gray, fine-grained, Byer member	50 to 90
Sandstone, coarse-grained, conglomerate, Berne member	0 to 2

Cuyahoga formation

Sandstone, conglomeratic in places, Black Hand member	100 to 120
Shales, gray, arenaceous, with thin sandstone layers, entire thickness not exposed, Cuyahoga shale	75

The limestone members of the Pennsylvanian are, in general, not strongly developed on the outcrop in Vinton County. Some are patchy in distribution and nodular in form, others are shaly in character, whereas still others are represented by nodular iron ores. As a quarry stone the Vanport limestone leads in importance. Small quarries in this member have operated at various times in Elk, Clinton, Wilkesville, Vinton, and Richland townships.

The Maxville limestone, which in normal succession is found immediately above the Logan formation and which forms the top of the Mississippian system on outcrops in Ohio, is not known to occur on the outcrop in Vinton County. Below drainage, however, erosional remnants of this limestone, varying in thickness from 10 to 60 feet, are penetrated in many wells drilled for oil and gas in the west central part of Brown Township. Below the Maxville no carbonate rocks are encountered by the drill until the Middle Devonian limestones are reached. These are found at depths below sea level varying from 300 feet in the northwest corner to about 1,700 feet in the southeast part of the county.

Boggs Member

The Boggs member, which is often represented by limestone and flint in Muskingum, Coshocton, and Tuscarawas counties, is a siliceous iron ore in Vinton County where it varies from 1 inch to 2 feet in thickness. Outcrops have been noted in Brown, Swan, Richland, Elk, and Clinton townships.

Lower Mercer Limestone

The outcrops of the Lower Mercer limestone occur over a broad belt extending across Vinton County including all or parts of Brown, Swan, Jackson, Richland, Elk, and Clinton townships. Concerning the character of the limestone Stout writes as follows: [1]

"In Vinton County the member varies greatly both in thickness and in character. It may be represented by a single bed of limestone, by limestone overlain or underlain by calcareous, fossiliferous shale, by two benches of limestone separated by fossiliferous shale, by dark flint, or by fossiliferous shale alone. The limestone layers vary in thickness from 1 inch to 1 foot 8 inches but they usually measure from 4 to 10 inches. The lower stratum of limestone is far more persistent than the upper one. The associated fossiliferous shales expand from a few inches to as much as 10 feet. The average of more than 50 measurements within the county shows that the mean thickness of fossiliferous shale and limestone is 3 feet 2 inches and of limestone along 7 inches."

Small economic importance can be attached to the Lower Mercer limestone in Vinton County as the limestone phase is generally too thin to be worked except to supply very local needs.

Upper Mercer Limestone

The Upper Mercer limestone is generally wanting on the outcrop in Vinton County. Its position is closely marked, however, by the thin but persistent Upper Mercer ore. At a few localities in Madison, Swan, and Jackson townships the ore is closely underlain by a few inches of siliceous limestone and flint representing this member. No economic importance can be attached to the limestone in this area.

Putnam Hill Limestone

The Putnam Hill horizon is generally represented in this county by fossiliferous shale at the base of which in some localities is thin shaly limestone a foot or less in thickness. The belt of outcrops extend from eastern Richland and eastern Clinton townships on the south to Jackson, Swan, and western Brown townships on the north but the member is probably best developed in Elk Township. The limestone is too thin to arouse much economic interest.

Zaleski Member

In Vinton County the Zaleski member has been recognized in southern Brown and southern Swan townships, along the high ridges in southeastern Jackson and eastern Richland townships, in Elk and western Madison townships, over small areas in Clinton Township, and along Pierce Run from Oreton to Radcliff in Vinton

[1] *Stout, Wilber, Geology of Vinton County: Geol. Survey Ohio Bull. 31, p. 121-122, 1927.*

Township. The member is best developed near McArthur, Hamden, and Zaleski. Concerning the characteristics Stout writes as follows: [1]

"The most characteristic material on the Zaleski horizon is a black or brownish black flint, hard and lustrous.... The exposed material is traversed by a network of fine cracks due to expansion changes. Aside from the true flint, the horizon also yields calcareous flint, siliceous limestone, calcareous shale, and iron ore. In the limy varieties the color varies from light gray to grayish brown, the shade decreasing as the lime increases. The iron ore under deep cover is a siderite but near the surface this has been changed to a limonite."

The Zaleski flint was used extensively by the aborigines as witnessed by the presence of many pits along the outcrop in Vinton County. The flint is of little value today although if properly milled the material is well adapted to the production of sand paper, for sand blast material, for ferrosilicon, and for similar uses. The Zaleski member has no economic value for its lime content.

The Zaleski member is well exposed at the south central edge of Section 14, Elk Township. As described by Wilber Stout, the section at this locality is as follows:

		Ft.	In.
Coal, weathered, Winters		2	0
Covered		3	0
Flint, black, curly, Zaleski		3	2
Coal, good	Ogan	-	8
Shale, dark	Ogan	-	5
Coal, good	Ogan	1	7
Shale and covered		19	0
Coal blossom, Brookville		2	0
Clay and covered		5	0

The 3 feet 2 inches of Zaleski flint exposed here was sampled in 1936 by R. A. Schoenlaub of the State Highway Testing Laboratory.

Sample No. 81

Chemical analysis of Zaleski flint from outcrop, Section 14, Elk Township, Vinton County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	94.72
Alumina, Al_2O_3	0.59
Ferric oxide, Fe_2O_3	0.10
Ferrous oxide, FeO	0.55
Iron disulphide, FeS_2	0.14
Magnesium oxide, MgO	0.02
Calcium oxide, CaO	1.29
Sodium oxide, Na_2O	0.06
Potassium oxide, K_2O	0.09
Water, hydroscopic, H_2O-	0.50
Water, combined, H_2O+	0.65
Carbon dioxide, CO_2	1.07
Titanium dioxide, TiO	0.09
Phosphorus pentoxide, P_2O_5	0.14
Sulphur trioxide, SO_3	<0.01
Manganous oxide, MnO	<0.01

[1] *Stout, Wilber, op. cit., p. 181.*

Carbon, organic, C	0.24
Hydrogen, organic, H	0.03
Total	100.28

The per cent of the various mineral components in the sample as computed (Lamborn) from the analysis is as follows:

Silicates, $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.50
Silica, SiO_2	94.03
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.12
Ferrous carbonate, $FeO.CO_2$	0.88
Iron disulphide, FeS_2	0.14
Titanium dioxide, TiO_2	0.09
Calcium phosphate, $3CaO.P_2O_5$	0.30
Calcium carbonate, $CaO.CO_2$	2.01
Magnesium carbonate, $MgO.CO_2$	0.04
Water, hydroscopic, H_2O-	0.50
Organic matter	0.27
Unbalanced components (deficiency CO_2, H_2O)	+0.40
Total	100.28

Vanport Limestone

In Vinton County the horizon of the Vanport limestone reaches the surface over a broad belt extending from Brown and Swan townships on the north to Wilkesville and Clinton townships on the south. Over this field the Vanport member is unsteady in its occurrence as it is wanting in many localities both through lack of deposition and through replacement by sandstone. Where present the member "may be represented by rather pure limestone, by cherty limestone, by chert or buhrstone, and by calcareous shale." [1]

"As a true limestone the deposits of most value are present along Raccoon Creek and its western tributaries in central Wilkesville Township, on the ridges in southeastern Clinton, along Pierce Run and Raccoon Creek in Vinton, along Flat Run in southeastern Madison, along the ridges in southeastern Elk, and on the main divide in northeastern Richland. Thin isolated deposits are also found in Brown, Swan, and Jackson townships." [2]

The thickness of the Vanport member in this county varies from a few inches to a maximum of about 10 feet. In the field of best limestone development outlined above the stone is generally light gray in color and massively developed, having a thickness ranging from 4 to about 8 feet. Chert nodules are of common occurrence embedded in the upper part of the limestone. Along Raccoon Creek in the southern part of Wilkesville Township the position of the Vanport is immediately above the Clarion coal but elsewhere in the county it is separated from the latter by shale varying in thickness from a few inches to 22 feet. Over small local areas the limestone is closely overlain by the Ferriferous ore.

In economic value the Vanport is the most important limestone outcropping in Vinton County. It was early quarried at a number of localities and utilized as flux stone in charcoal furnaces. Later uses include limestone for the production of Portland cement and agricultural lime, road stone, and concrete aggregate. At different times quarries have operated in Wilkesville, Vinton, Elk, Clinton, and Richland townships.

In Section 30, Elk Township, the Vanport limestone was formerly quarried and calcined for agricultural purposes on the Charles Dayton property. Wilber

[1] *Stout, Wilber, op. cit., p. 256.*

[2] *Idem.*

Stout has described the exposures as follows: [1]

	Ft.	In.
Soil	2	0
Limestone, Vanport	6	0
Covered	10	0
Coal blossom, Clarion or No. 4a	2	0
Shale and covered	24	7
Coal blossom, Winters	1	0

The Vanport limestone at the locality described above was sampled for chemical analysis in 1922 by Wilber Stout. [2]

Sample No. 1012

Chemical analysis of Vanport limestone from old quarry on Charles Dayton property, Section 30, Elk Township, Vinton County, D. J. Demorest, analyst

	Per cent
Silica, SiO_2	1.80
Alumina, Al_2O_3	1.80
Ferric oxide, Fe_2O_3	1.63
Calcium oxide, CaO	51.23
Magnesia, MgO	0.64
Titanium dioxide, TiO_2	0.02
Phosphorus pentoxide, P_2O_5	0.15
Sulphur trioxide, SO_3	0.79
Loss at 105°C	1.50

As converted by Wilber Stout into the probable mineral compounds present in the sample, the results are as follows: [3]

Clay base, $Al_2O_3.2SiO_2.2H_2O$	3.84
Aluminum hydroxide, $Al_2O_3.3H_2O$	0.46
Iron disulphide, FeS_2	0.60
Ferrous carbonate, $FeO.CO_2$	1.79
Titanium dioxide, TiO_2	0.02
Calcium phosphate, $3CaO.P_2O_5$	0.33
Calcium carbonate, $CaO.CO_2$	91.16
Magnesium carbonate, $MgO.CO_2$	1.34
Total	99.54

The Vanport limestone was formerly quarried for furnace flux on the Vinton Furnace tract in the northern part of Section 36, Elk Township. A description of the exposures in the old quarry as recorded by Wilber Stout in 1922 is as follows: [4]

		Ft.	In.
Limestone, flinty	Vanport	1	0
Limestone, gray, hard		8	0
Limestone, not well exposed		--	--

[1] *Stout, Wilber, op. cit., p. 259.*

[2] *Stout, Wilber, op. cit., p. 266.*

[3] *Idem.*

[4] *Stout, Wilber, op. cit., p. 260.*

The 8-foot bed of Vanport limestone was sampled by Wilber Stout in 1922 for chemical analysis. The results are as follows: [1]

Sample No. 1013

Chemical analysis of Vanport limestone from old quarry on Vinton Furnace land, Section 36, Elk Township, Vinton County, D. J. Demorest, analyst

	Per cent
Silica, SiO_2	0.69
Alumina, Al_2O_3	0.78
Ferric oxide, Fe_2O_3	1.01
Lime, CaO	53.92
Magnesia, MgO	0.12
Titanium dioxide, TiO_2	Trace
Phosphorus pentoxide, P_2O_5	0.12
Sulphur trioxide, SO_3	0.26
Loss at 105°C	0.81

Converted by Wilber Stout into the probable mineral compounds the composition is as follows:

Clay base, $Al_2O_3.2SiO_2.2H_2O$	1.49
Aluminum hydroxide, $Al_2O_3.3H_2O$	0.29
Iron disulphide, FeS_2	0.19
Ferrous carbonate, $FeO.CO_2$	1.27
Titanium dioxide, TiO_2	Trace
Calcium phosphate, $3CaO.P_2O_5$	0.26
Calcium carbonate, $CaO.CO_2$	96.04
Magnesium carbonate, $MgO.CO_2$	0.25
Total	99.79

The Vanport limestone is well developed on the land of the Puritan Brick Company, near Hamden Furnace in Clinton Township. Exposures occurring in the northwest part of Section 27 are described by Wilber Stout as follows:

		Ft.	In.
Shale, clay, and soil		10	0
Limestone, dark gray, massive, upper part stained with iron oxides, Vanport		6	10
Shale, black, bony	Clarion or No. 4a	1	7
Coal, some shale partings	Clarion or No. 4a	1	1
Clay and bone	Clarion or No. 4a	--	4
Coal, good	Clarion or No. 4a	1	4
Shale with pyrite	Clarion or No. 4a	--	1 1/2
Coal	Clarion or No. 4a	--	11
Clay, dark, somewhat flinty		1	6
Clay, light		3	6
Clay, arenaceous		4	0
Sandstone and covered		10	0

The Vanport limestone at this locality, having a thickness of 6 feet 10 inches, was sampled on October 23, 1935, by Wilber Stout for chemical analysis.

[1] *Stout, Wilber, op. cit., p. 266.*

Sample No. 80

Chemical analysis of Vanport limestone from outcrop on property of Puritan Brick Co., Section 27, Clinton Township, Vinton County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	1.90
Alumina, Al_2O_3	1.06
Ferric oxide, Fe_2O_3	1.10
Ferrous oxide, FeO	2.01
Iron disulphide, FeS_2	0.06
Magnesium oxide, MgO	0.44
Calcium oxide, CaO	51.05
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.04
Water, hydroscopic, H_2O-	0.14
Water, combined, H_2O+	0.35
Carbon dioxide, CO_2	41.62
Titanium dioxide, TiO_2	0.04
Phosphorus pentoxide, P_2O_5	0.16
Sulphur trioxide, SO_3	0.02
Manganous oxide, MnO	0.21
Carbon, organic, C	0.06
Hydrogen, organic, H	--
Total	100.28

The per cent of each of the mineral compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.58
Hydrated silicates $Al_2O_3.2H_2O.2SiO_2$	2.11
Silica, SiO_2	0.65
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	1.29
Ferrous carbonate, FeS_2	3.24
Iron disulphide, FeS_2	0.06
Titanium dioxide, TiO_2	0.04
Calcium phosphate, $3CaO.P_2O_5$	0.35
Calcium sulphate, $CaO.SO_3$	0.03
Calcium carbonate, $CaO.CO_2$	90.75
Magnesium carbonate, $MgO.CO_2$	0.92
Manganese carbonate, $MnO.CO_2$	0.34
Water, hydroscopic, H_2O-	0.14
Organic matter	0.06
Unbalanced components (excess CO_2, H_2O)	-0.28
Total	100.28

The quarry of the Clarion Lime Company is located near the mouth of Indiancamp Run in the northeast quarter of Section 28, Wilkesville Township. Here the limestone which occurs in good thickness and purity is pulverized and marketed for agricultural use. The exposures in the quarry are described as follows:

	Ft.	In.
Sandstone, shaly, and sandy shale	4	0
Shale, bluish gray	3	0
Coal, blocky, Lower Kittanning or No. 5	1	2
Clay, gray, plastic, with ore nodules	2	0
Shale, dark, carbonaceous, micaceous, Lawrence coal horizon	--	3

Clay, bluish gray, plastic		2	2
Clay, gray, sandy		3	8
Clay shale, bluish		3	0
Ore, Ferriferous		--	8
Limestone, light bluish gray to pink, dense to finely crystalline, one layer	Vanport	3	4
Limestone, light brownish gray, dense to finely crystalline, one layer	Vanport	1	2
Limestone, bluish gray, tough, one layer	Vanport	2	5
Shale, black		--	2
Coal, part exposed, Clarion or No. 4a		2	0
Bottom of quarry.			

The limestone exposed in this quarry having a total thickness of 6 feet 11 inches was sampled by R. E. Lamborn on September 15, 1942, for chemical analysis.

Sample No. 390

Chemical analysis of Vanport limestone from quarry of Clarion Lime Company, Section 28, Wilkesville Township, Vinton County, Nalin Laboratories, analysts.

	Per cent
Silica, SiO_2	0.41
Alumina, Al_2O_3	0.35
Ferric oxide, Fe_2O_3	0.39
Ferrous oxide, FeO	1.14
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	0.66
Calcium oxide, CaO	53.52
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.08
Potassium oxide, K_2O	0.14
Water, hydroscopic, H_2O-	0.08
Water, combined, H_2O+	0.05
Carbon dioxide, CO_2	42.24
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.09
Sulphur trioxide, SO_3	0.83
Manganous oxide, MnO	0.01
Carbon, organic, C	0.15
Hydrogen, organic, H	0.02
Total	100.17

The per cent of each of the compounds probably present in the sample as computed (Lamborn) from the chemical analysis is given below:

Silica and hydrated aluminum silicates of potassium and sodium	0.98
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	0.45

Ferrous carbonate, $FeO.CO_2$	1.84
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.01
Calcium phosphate, $3CaO.P_2O_5$	0.20
Calcium sulphate, $CaO.SO_3$	1.41
Calcium carbonate, $CaO.CO_2$	94.40
Magnesium carbonate, $MgO.CO_2$	1.38
Manganese carbonate, $MnO.CO_2$	0.01
Water, hydroscopic, H_2O-	0.08
Organic matter	0.17
Unbalanced components (excess CO_2, H_2O)	-0.76
Total	100.17

Hamden Member

The Hamden horizon, which bears limestone of fair purity over small areas in Muskingum County, is marked in Vinton County by patchy deposits of thin nodular iron ore. The ore has been recognized at a few places in Elk, Madison, Brown, and Clinton townships.

Lower Freeport Limestone

The outcrops of the Lower Freeport limestone in this county are confined to Brown, Madison, Vinton, Knox, and Wilkesville townships. In none of these townships is it a satisfactory source for limestone as the deposits consist of nodular, highly ferruginous limestone embedded in the Lower Freeport clay.

Upper Freeport Limestone

In mode of occurrence and lack of economic importance the Upper Freeport limestone ranks with the Lower Freeport limestone mentioned above. In Brown, Madison, Vinton, Knox, and Wilkesville townships where the Upper Freeport outcrops its character is generally thin and nodular and its composition is often marked by a high iron content.

Mahoning Limestone

The Mahoning limestone is generally wanting in this county although thin deposits have been noted at a few localities by Wilber Stout in Brown, Vinton, and Wilkesville townships. Like the Freeport limestones it is thin and nodular in character arousing no interest for its economic possibilities.

Brush Creek Member

Outcrops of the Brush Creek in Vinton County are confined to the high ridges in eastern Brown, eastern Madison, eastern Vinton, Knox, and Wilkesville townships. The member consists of two calcareous beds separated by sandstone and shale which have a total average thickness of about 27 feet. The upper bed, the thicker and more persistent of the two, is composed of gray siliceous limestone or of gray and black flint having a depth ranging from a few inches to 5 feet or more. The lower bed generally has a thickness of only a few inches and may consist of fossiliferous gray impure limestone or black flint. The thin development of the Brush Creek renders it unattractive except for local needs and its siliceous character makes it unsuited to uses where a high carbonate content is desired.

Cambridge Limestone

The Cambridge limestone has no economic importance in Vinton County as its outcrops are confined to a few high knobs in Knox and Wilkesville townships where the limestone measures less than 10 inches in thickness.

WASHINGTON COUNTY

General Considerations

Washington County embracing an area of 642 square miles is the largest county in Ohio bordering on the Ohio River and is surpassed in total area by only four counties in the State, namely, Ashtabula, Licking, Ross, and Muskingum. Physiographically Washington County lies in the unglaciated part of the maturely dissected Allegheny Plateau. Glacial drift deposits are wanting on the uplands but outwash deposits of glacial origin are present in some measure along the Muskingum and Ohio valleys. The bedrocks outcropping across this county belong to the Conemaugh and Monongahela series of the Pennsylvanian system and to the overlying Permian system, and represent a total vertical thickness a little in excess of 1,050 feet. The patterns of outcrop of the various series and members are by no means uniform and regular owing in part to the structural conditions that prevail. The western part of the county extends across the Parkersburg-Lorain syncline the axis of which can be represented roughly by a line from Parkersburg, through Waterford to Coshocton. From the bottom of this trough the beds rise rather uniformly to the west but much more steeply and irregularly to the east where they form a structural crest, the summit of which can be represented by an irregular line extending in a northern direction from the Ohio River at Belmont, West Virginia, to Lebanon in Monroe County. Owing to the lack of structural uniformity and to arrangement of the chief water courses which traverse the structural trends, beds of Conemaugh age outcrop along the valley of the Little Muskingum River in the east central part, in the valley of Duck Creek in the north central part, and along the Ohio River Valley near Newport in the southeast part of the county. Outcrops of the overlying Monongahela series are more extensively distributed along the same valleys and are also found along the Muskingum River Valley and its chief tributaries in the northwest quarter of the county and along the valley of the Little Hocking River in the southwest quarter. The Permian strata which overlie the Monongahela outcrop over an estimated four-fifths of area including the uplands and high hills and ridges. A generalized section showing the stratigraphic sequence in this county and the approximate thickness of recognized units, as compiled from several sources, [1] is as follows:

General Section of Bedrocks Outcropping in Washington County

Permian system	Ft.	In.
Shale red and gray with thin sandstone and an occasional thin coal blossom. Members not differentiated	450	0
Sandstone, local, Lower Marietta coal and black shale, discontinuous, Washington	3	0

[1] *The Conemaugh section has been derived from Geology of Newport Township, Washington County, Ohio: by William H. Smith, a thesis (unpublished) presented to the Department of Geology, Ohio State University, in 1948. The details of the Monongahela series has been deduced from sections and unpublished notes by Wilber Stout, whereas the succession of Permian strata is essentially that described by C. R. Stauffer and C. R. Schroyer, The Dunkard series of Ohio: Geol. Survey Ohio Bull. 22, pp. 115-133, 1920.*

Shale, red and gray, with thin discontinuous sandstone, Mannington sandstone horizon	85	0
Coal and black shale, locally developed, Waynesburg A	1	0
Shale and sandstone, Waynesburg sandstone horizon	39	0
Shale, gray, Cassville	5	0
Pennsylvanian system		
Monongahela series		
Coal, only locally present, Waynesburg or No. 11	-	4
Clay shale, light, impure	3	5
Sandstone, very local, Gilboy	6	7
Shale, gray to dark, siliceous	6	0
Coal, locally represented, Little Waynesburg	-	3
Clay, light, grainy	3	0
Limestones and marly shales, local, Waynesburg	6	6
Sandstone, massive, very local, Uniontown	14	3
Shale, gray to drab, siliceous	19	0
Coal, rather persistent but thin, Uniontown or No. 10	-	6
Clay and clay shale, impure	2	6
Limestones and marly shales, usually coalesces with others below, Uniontown	6	0
Sandstone, very local, Arnoldsburg	5	0
Coal, generally wanting, Arnoldsburg	-	-
Limestones and calcareous shales, persistent, Arnoldsburg	35	0
Shale, olive green, wanting, Fulton	-	-
Limestones and calcareous shales, persistent, Benwood	27	10
Sandstone, usually present and massive, Upper Sewickley	21	0
Shale, gray to dark, local	5	0
Coal, persistent, Sewickley, Meigs Creek or No. 9	3	6
Clay, light, calcareous, impure	2	8
Shale, gray, siliceous	6	6
Sandstone, locally present, Lower Sewickley	9	7
Shale, gray, siliceous	4	6
Coal, generally present, Fishpot	-	2
Limestone and calcareous shales, persistent, Fishpot	20	7
Sandstone, locally present, Pomeroy or Redstone	5	0
Shale, gray, siliceous	1	0
Coal, very unsteady, Redstone or Pomeroy	-	1
Limestones and marly shales, unsteady, Redstone	7	0
Sandstone, massive, unsteady, Upper Pittsburgh	9	6
Shale, gray, siliceous	6	0
Coal, persistent, variable, Pittsburgh or No. 8	-	6
Conemaugh series		
Limestone, generally gray; in layers with clay shale interstratified, Pittsburgh	2	0
Clay shale, variegated soft, with nodules and nodular beds of limestone	40	0

Sandstone, thin-bedded, with some shale partings, Connellsville	20	0
Coal, shaly, and clay shale, Clarksburg	2	8
Shale, red, argillaceous	15	0
Sandstone, greenish gray, fine-grained, micaceous, Morgantown	10	0
Shale, carbonaceous to coaly, Elk Lick	-	1
Limestone in several thin layers separated by clay shale partings, Elk Lick	2	6
Shale and covered	50	0
Limestone, dark gray, dense, fossiliferous, Ames	1	0
Shale and shaly sandstone	19	10
Coal, Harlem	1	8
Clay shale	1	8
Limestone, shaly to nodular	1	0
Shale and covered	21	0
Sandstone, gray, medium to coarse-grained, Cow Run	29	0

The potential limestone resources of Washington County are confined chiefly to the members of the Monongahela series and to a less extent to the thin limestones in the upper part of the Conemaugh series. In general the Monongahela limestone members in this county contain a larger per cent of calcareous shale in proportion to the limestone than is characteristic of the same members farther north along the outcrop. Hence their potential value as sources of stone is somewhat less. The chief limestone members exposed in Washington County in ascending order are, Pittsburgh, Redstone, Fishpot, and Benwood-Arnoldsburg-Uniontown beds.

No limestones of the coal-bearing series are known to occur in minable thickness below drainage in Washington County. However, the Maxville limestone, which is due immediately below the coal measures, is generally present in Ludlow, Grandview, Independence, eastern Liberty, and eastern Newport townships, where, according to records of wells drilled for oil and gas, it is present with a thickness varying from a few feet to 140 feet and is reached at depths below the surface of 1,100 to 1,700 feet. It is also reported in the records of a few wells in Barlow and Decatur townships but the formation there is generally thin.

Ames Limestone

The only exposures of Ames limestone in Washington County are found along the Ohio River Valley near Newells Run, Newport Township, where the river has cut across the Burning Springs anticlinal structure. Here the member is a gray, dense fossiliferous stone, rarely exceeding one foot in thickness. Little potential economic value is indicated.

Elk Lick Limestone

Fifty feet above the Ames in the Newells Run area there is an impure limestone of the fresh or brackish water type averaging 2 1/2 feet in thickness which is correlated with the Elk Lick limestone. [1] The member consists of several layers of medium to dark gray dense limestone which tends to be more shaly and impure in the lower part. It has slight economic possibilities.

[1] *Smith, Wm. H., op. cit., p. 27.*

Pittsburgh Limestone

The Pittsburgh limestone horizon is due above drainage along the Ohio River Valley in southeastern Newport Township, in the Little Muskingum River Valley in Lawrence and Ludlow townships, in the valley of Duck Creek north of northern Fearing Township, and in the vicinity of Newport, Newport Township. The position of the limestone is immediately below the Pittsburgh coal which in these areas is either wanting or very poorly represented on the outcrop. The Pittsburgh limestone is best known along Duck Creek Valley where its thickness varies from a few inches to as much as 14 or 15 feet. In places the member is composed of dense compact limestone layers separated by calcareous shales. Elsewhere the entire member is somewhat impure and shaly. The Pittsburgh limestone is not known to have been utilized to any extent in Washington County.

Redstone Limestone

The horizon of the Redstone limestone is generally occupied by sandstones and sandy shales where it outcrops along the Ohio River and Newells Run in southeastern Newport Township and along Duck Creek in northern Fêaring, Salem, and Aurelius townships. Limestone on the Redstone horizon is present in places along the outcrop of its horizon in the valleys of the Little Muskingum River and its tributaries in Lawrence, Ludlow, and Liberty townships. It is well developed along Sycamore Fork in the east central part of Section 14, where the following measurements were secured. Here the Pittsburgh coal outcrops at stream level.

		Ft.	In.
Shale, sandy, and shaly sandstone		10	0
Shale, bluish gray		4	0
Shale, with a few thin limestone layers, not sampled	Redstone	1	10
Limestone, bluish gray, hard, sampled	Redstone	-	8
Shale, calcareous, not sampled	Redstone	-	4
Limestone, bluish gray, hard, compact, sampled	Redstone	-	4
Clay shale, not sampled	Redstone	-	2
Limestone, hard, bluish gray, sampled	Redstone	-	6
Clay shale, not sampled	Redstone	-	1
Limestone, bluish gray, hard, sampled	Redstone	1	0
Shale, calcareous, not sampled	Redstone	-	10
Limestone bluish gray, hard, sampled	Redstone	-	6
Shale, calcareous, with a few lens-shaped layers of limestone, not sampled	Redstone	1	4

			Feet	Inches
Limestone, bluish gray, hard, compact, sampled	Redstone (cont.)	....	-	9
Shale, calcareous, not sampled		....	-	3
Limestone, hard, bluish gray, sampled		....	-	8
Shale, carbonaceous, not sampled		....	-	10
Limestone, bluish gray, hard, sampled		....	-	4
Shale, bluish gray, calcareous, not sampled		....	-	5
Limestone, bluish gray, hard, compact, sampled		....	1	0
Clay shale, bluish, not sampled		....	2	2
Coal, Pittsburgh or No. 8			1	4

The limestone layers described above, having a total thickness of 5 feet 9 inches, were sampled by R. E. Lamborn on June 24, 1942, for chemical analysis.

Sample No. 385

Analysis of Redstone limestone from outcrop along Sycamore Fork, Section 14, Liberty Township, Washington County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	9.10
Alumina, Al_2O_3	2.98
Ferric oxide, Fe_2O_3	1.53
Ferrous oxide, FeO	1.07
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO	3.08
Calcium oxide, CaO	43.28
Strontium oxide, SrO	<0.01
Barium oxide, BaO	0.098
Sodium oxide, Na_2O	0.17
Potassium oxide, K_2O	0.38
Water, hydroscopic, H_2O-	0.15
Water, combined, H_2O+	0.28
Carbon dioxide, CO_2	37.46
Titanium dioxide, TiO_2	0.15
Phosphorus pentoxide, P_2O_5	0.05
Sulphur trioxide, SO_3	0.15
Manganous oxide, MnO	0.02
Carbon, organic, C	0.21
Hydrogen, organic, H	0.03
Total	100.188

As computed (Lamborn) from the chemical composition, the per cent of each of the chief mineral constituents present in the sample is as follows:

Silicates	$(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	5.309
	$Al_2O_3.2SiO_2.2H_2O$	2.297

Silica, SiO_2	5.587
Hydrated ferric oxide, $2Fe_2O_3 . 3H_2O$	1.788
Ferrous carbonate, $FeO.CO_2$	1.724
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.150
Calcium phosphate, $3CaO.P_2O_5$	0.109
Calcium sulphate, $CaO.SO_3$	0.168
Barium sulphate, $BaO.SO_3$	0.149
Calcium carbonate, $CaO.CO_2$	77.017
Magnesium carbonate, $MgO.CO_2$	6.437
Manganese carbonate, $MnO.CO_2$	0.032
Water, hydroscopic, H_2O-	0.150
Organic matter	.240
Unbalanced components (excess CO_2, H_2O)	-0.969
Total	100.188

Fishpot Limestone

The Fishpot limestone occurring in the interval between the Fishpot coal above and the Redstone coal below is not well represented on the outcrop in Washington County. Where exposures are due in Newport, Lawrence, Ludlow, Fearing, Salem, and Aureluis townships, the horizon of this limestone is pretty generally occupied by sandstones and sandy shales with an occasional few feet of calcareous shale and thin limestone representing the Fishpot limestone occurring close below the horizon of the Fishpot coal.

Benwood-Arnoldsburg-Uniontown Limestones

The Meigs Creek and Uniontown coal horizons in Washington County are separated on an average by 108 feet of strata consisting of 20 feet or more of sandstone and shale at the base, above which is a series of calcareous shales with some interbedded limestone. The Benwood, Arnoldsburg, and Uniontown limestones occur in this series, but they are not readily distinguishable in this county owing to the general absence of the Fulton Green shale separating the two lower limestone members and to the general lack of the Arnoldsburg coal and sandstone between the Uniontown and Arnoldsburg limestones. The distribution of outcrops of this limestone and shale series is in general confined to the townships situated along the northern and northwestern borders of the county, to the Little Muskingum River Valley in Lawrence Township, and to the Ohio River Valley in Newport Township. In Washington County this series consists in large part of shale with occasional thin lenses and layers of limestone. Locally the limestone beds become thicker and more numerous and present possibilities for quarry operations on a small scale.

Limestone overlying the Meigs Creek coal and probably belonging to the lower part of the Benwood-Uniontown series was being quarried in 1942 in Waterford Township by the Waterford Quarries Company. The quarry is located along the valley of Wolf Creek just east of the road forks, 1 1/4 miles southwest of Waterford. The stone is pulverized at the quarry and marketed as agricultural limestone. A section of the exposures follows.

		Ft.	In.
Limestone, nodular, not sampled	Benwood-Uniontown	-	6
Shale, calcareous, not sampled		-	2

			Feet	Inches
Limestone, nodular, not sampled.....	Benwood-Uniontown (cont.)	....	1	0
Shale, calcareous, not sampled.....		....	1	0
Limestone, bluish to brownish gray, hard, one layer, sampled.............		....	2	0
Limestone, gray, dense texture, somewhat brecciated, sampled		....	-	7
Limestone, bluish to light brownish gray, somewhat brecciated, sampled		....	1	0
Limestone, light buff with bluish gray angular fragments embedded in it, sampled		....	1	0
Limestone, bluish to brownish gray, dense texture, sampled		....	1	0
Shale, calcareous, not sampled.....		....	-	1/2
Limestone, bluish gray, dense texture, sampled		....	-	10
Limestone, bluish gray, dense, brittle, sampled		....	1	6
Limestone, bluish gray, not sampled..................			1	6

Limestone layers indicated above having a combined thickness of 7 feet 11 inches were sampled by R. E. Lamborn on June 11, 1942, for chemical analysis.

Sample No. 378

Chemical analysis of Benwood-Uniontown limestone from quarry of Waterford Quarries Company, near Waterford, Waterford Township, Washington County, Nalin Laboratories, analysts

	Per cent
Silica, SiO_2	11.11
Alumina, Al_2O_3	2.28
Ferric oxide, Fe_2O_3	0.02
Ferrous oxide, FeO..	0.93
Iron disulphide, FeS_2	<0.01
Magnesium oxide, MgO..	7.14
Calcium oxide, CaO	37.03

Strontium oxide, SrO	<0.01
Barium oxide, BaO	0.12
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	<0.01
Water, hydroscopic, H_2O-	0.16
Water, combined, H_2O+	3.25
Carbon dioxide, CO_2	37.34
Titanium dioxide, TiO_2	0.01
Phosphorus pentoxide, P_2O_5	0.03
Sulphur trioxide, SO_3	0.06
Manganous oxide, MnO	0.09
Carbon, organic, C	0.39
Hydrogen, organic, H	0.05
Total	100.03

The per cent of each of the mineral compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	0.25
Silicates $Al_2O_3.2SiO_2.2H_2O$	5.52
Silica, SiO_2	8.42
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.02
Ferrous carbonate, $FeO.CO_2$	1.50
Iron disulphide, FeS_2	<0.01
Titanium dioxide, TiO_2	0.01
Calcium phosphate, $3CaO.P_2O_5$	0.07
Barium sulphate, $BaO.SO_3$	0.18
Calcium carbonate, $CaO.CO_2$	66.03
Magnesium carbonate, $MgO.CO_2$	14.92
Manganese carbonate, $MnO.CO_2$	0.14
Water, hydroscopic, H_2O-	0.16
Organic matter	0.44
Unbalanced components (deficiency CO_2, H_2O)	+2.37
Total	100.03

Limestone belonging to the Benwood-Uniontown series was formerly quarried on a small scale on the E. L. Waite property in the northwest quarter of Section 26, Wesley Township. The workings are located west of the northwest-southeast road along a small tributary to Coal Run. Here limestone and interstratified shale having a total thickness of 8 feet 8 inches are exposed (1946) as described in the following section.

		Ft.	In.
Limestone, light brownish gray, dense, with veinlets of calcite, sampled	Benwood-Uniontown	1	0
Shale, calcareous, not sampled		-	1
Limestone, light brownish gray, dense, with veinlets of calcite, sampled		-	11
Shale, calcareous, olive color, not sampled		1	11

Limestone, dense, hard, sampled....	Benwood-Uniontown (cont.)	....	-	6
Clay shale, not sampled		....	-	2
Limestone, dense, argillaceous, brittle, breaks with a flint-like fracture, sampled		....	1	5
Shale, olive gray, calcareous, not sampled......		....	1	6
Limestone, dense, argillaceous, not sampled......		....	-	2
Shale, bluish, argillaceous, not sampled......		....	1	0

The limestone layers indicated in the above description were sampled by R. E. Lamborn on July 25, 1946.

Sample No. 405

Chemical analysis of Benwood-Uniontown limestone from old quarry on E. L. Waite, property, Section 26, Wesley Township, Washington County, E. Chadbourn, analyst

	Per cent
Silica, SiO_2	8.69
Alumina, Al_2O_3	1.72
Ferric oxide, Fe_2O_3	0.32
Ferrous oxide, FeO	0.89
Iron disulphide, FeS_2	0.07
Magnesium oxide, MgO	5.49
Calcium oxide, CaO	42.55
Sodium oxide, Na_2O	0.09
Potassium oxide, K_2O	0.30
Water, hydroscopic, H_2O-	0.13
Water, combined, H_2O+	0.64
Carbon dioxide, CO_2	38.85
Titanium dioxide, TiO_2	0.07
Phosphorus pentoxide, P_2O_5	0.03
Sulphur trioxide, SO_3	0.03
Manganous oxide, MnO	0.10
Total	99.97

The per cent of each of the various mineral components in Sample No. 405 computed (Lamborn) from the chemical analysis is given below.

Silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	3.65
Silicates $Al_2O_3.2SiO_2.2H_2O$	0.76
Silica, SiO_2	6.67
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.37
Ferrous carbonate, $FeO.CO_2$	1.44
Iron disulphide, FeS_2	0.07
Titanium dioxide, TiO_2	0.07
Calcium phosphate, $3CaO.P_2O_5$	0.07
Calcium sulphate, $CaO.SO_3$	0.05

Calcium carbonate, $CaO.CO_2$	75.84
Magnesium carbonate, $MgO.CO_2$	11.47
Manganese carbonate, $MnO.CO_2$	0.16
Water, hydroscopic, H_2O-	0.13
Unbalanced components (excess CO_2, H_2O)	-0.78
Total	99.97

Waynesburg Limestone

The stratigraphic position of the Waynesburg limestone is close below the Little Waynesburg coal. Neither the coal nor the limestone is strongly expressed in Washington County. In some localities in Salem and Fearing townships where the coal horizon has been recognized it is underlain by a few feet of calcareous shale, sometimes pink in hue, which may contain nodules of limestone. The limestone has no economic importance in this county.

WAYNE COUNTY

General Considerations

The bedrocks which reach the surface in Wayne County belong to the Mississippian and Pennsylvanian systems and represent a total vertical thickness of approximately 875 feet. The strata of Mississippian age consist in this county of sandstone and shale with one or two thin beds of conglomerate. These rocks outcrop over an area of about 431 square miles including the northwest half and the east central part. The limestone formations are confined to the Pottsville and Allegheny subdivisions of the Pennsylvanian with outcrops distributed over parts of Clinton, Franklin, Salt Creek, Paint, Sugar Creek, Baughman, Chippewa, Milton, East Union, and Wooster townships. Strata of Pennsylvanian age are present over an area of about 125 square miles but owing to the widespread distribution of the glacial drift outcrops are few in number. A generalized section of the bedrocks outcropping in Wayne County is as follows: [1]

Generalized Section of Bedrocks Outcropping in Wayne County

Pennsylvanian system	Ft.	In.
Allegheny series		
Sandstone and shale	50	0
Coal, Lower Kittanning or No. 5	3	0
Clay, siliceous	5	6
Sandstone and shale	30	0
Limestone, gray, Putnam Hill	3	6
Coal, Brookville, or No. 4	2	6
Pottsville series		
Clay, siliceous	4	0
Sandstone and shale	30	0
Coal, Tionesta or No. 3b	1	0
Clay	3	0
Sandstone and shale	15	0
Limestone, dark blue, flinty, Upper Mercer	2	6
Coal, variable, Bedford	1	0
Clay, siliceous	6	0
Sandstone and shale	20	0

[1] *Conrey, G. W., Geology of Wayne County: Geol. Survey Ohio Bull. 24, pp. 49, 92, 111, 1921.*

Limestone, blue, hard, Lower Mercer	2		0
Coal, variable, Middle Mercer	1		0
Sandstone and shale	80		0
Coal, Quakertown or No. 2	1		0
Clay	5		0
Sandstone and shale	55		0
Coal, Sharon or No. 1	5		0
Conglomerate, Sharon	50		0
Mississippian system			
Maxville limestone, wanting.			
Logan formation			
Sandstone, fine-grained, Vinton	180		
Conglomerate, Allensville	3/4	to	2
Sandstone, fine-grained, Byer	50	to	80
Conglomerate and coarse sandstone, Berne	2	to	10
Cuyahoga formation			
Shale, changing laterally to coarse sandstone, Black Hand	70	to	80
Sandstone, fine-grained, Armstrong	25	to	35
Shale and sandstone, Burbank	150		

Only three limestones occur above drainage in this county, namely the Lower Mercer, the Upper Mercer, the Putnam Hill. All of these members are generally thin over the area. Small quarries for the production of agricultural limestone and road stone for local needs have operated at a number of places in Paint and Franklin townships.

The Pennsylvanian system in Wayne County is underlain by thick deposits of sandstone and shale measuring many hundreds of feet in depth. In deep wells sunk for oil and gas such beds are encountered by the drill until the top of the Middle Devonian limestones are reached at depths below sea level ranging from 500 feet in the northwest corner to about 1, 500 feet in the southeast corner of the county.

Lower Mercer Limestone

The Lower Mercer limestone has slight economic importance in Wayne County as the member is generally thin, as it is apparently discontinuous, and as the recorded exposures are limited to a few widely scattered areas in Baughman, Sugar Creek, and Paint townships. [1] Elsewhere in the county where the Lower Mercer is due the limestone has apparently been replaced by sandstone and shale. Where present the limestone varies from a few inches to 4 feet in thickness.

Upper Mercer Limestone

A few scattered exposures of Upper Mercer limestone have been recorded as occurring in Sugar Creek, Paint, Salt Creek, and Franklin townships. [2] At all places the stone is dark bluish in color and tends to be hard and flinty in character. It varies in thickness from 1 to 3 feet but averages about 2 feet. As a potential source for limestone the Upper Mercer has little importance in Wayne County.

[1] *Conrey, G. W., op. cit., pp. 100-104.*

[2] *Conrey, G. W., op. cit., pp. 107-109.*

Putnam Hill Limestone

The Putnam Hill is the most important as a source of limestone in Wayne County. Its thickness on the outcrop is somewhat variable ranging, according to Conrey, from 1 foot to 5 1/2 feet. Sandstone cut-outs are believed to be comparatively few in number. Conrey describes this limestone in Wayne County as follows: [1]

"The Putnam Hill is a hard, dense, gray limestone which is known locally as the 'gray limestone' to distinguish it from the Upper Mercer which is the 'blue limestone'. It is commonly spoken of as the 'plate limestone', because of a tendency to split into beds of 2 to 4 inches, as a result of which it can be easily quarried, but where well under cover it tends to be more massive. It is everywhere quite fossiliferous."

The horizon of the Putnam Hill limestone occurs near the tops of the highest hills in the southeastern half of Sugar Creek Township but, owing to the glacial drift deposits, exposures are few in number. The limestone is generally present at altitudes around 1,200 feet in Paint Township and the eastern half of Salt Creek Township. South of Mount Eaton in southern Paint Township this limestone has a thickness of about 5 feet. It is generally present near the hilltops in the southeastern and south central parts of Franklin Township.

The Putnam Hill limestone was formerly stripped along the outcrop and quarried for agricultural lime on the Clinton M. Harrold property in Section 24, Paint Township. The stone was calcined on the premises before marketing. A description of the exposure is given below:

	Ft.	In.
Limestone, bluish gray, dense, somewhat brittle, Putnam Hill	3	2
Shale, dark, soft	--	4
Coal, reported to thicken under cover to 2 feet 4 inches, Brookville or No. 4	2	0

A sample of the Putnam Hill secured at this locality by R. E. Lamborn on May 21, 1941, has a composition as given below.

Sample No. 335

Chemical analysis of Putnam Hill limestone from quarry on Clinton M. Harrold property, Section 24, Paint Township, Wayne County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	3.53
Alumina, Al_2O_3	1.70
Ferric oxide, Fe_2O_3	0.03
Ferrous oxide, FeO	1.12
Iron disulphide, FeS_2	0.05
Magnesium oxide, MgO	1.02
Calcium oxide, CaO	50.16
Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.03
Potassium oxide, K_2O	0.10
Water, hydroscopic, H_2O-	0.25
Water, combined, H_2O+	0.49

[1] *Conrey, G. W., Op. cit., p. 113.*

Carbon, dioxide, CO_2	41.00
Titanium dioxide, TiO_2	0.08
Phosphorus pentoxide, P_2O_5	0.18
Sulphur trioxide, SO_3	0.09
Manganous oxide, MnO	0.11
Carbon, organic, C	0.14
Hydrogen, organic, H	0.01
Total	100.09

The per cent of each of the various compounds probably present in the sample has been computed (Lamborn) from the chemical analysis.

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_3O$	1.21
$Al_2O_3.2SiO_2.2H_2O$	3.11
Silica, SiO_2	1.53
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.04
Ferrous carbonate, $FeO.CO_2$	1.80
Iron disulphide, FeS_2	0.05
Titanium dioxide, TiO_2	0.08
Calcium phosphate, $3CaO.P_2O_5$	0.39
Calcium sulphate, $CaO.SO_3$	0.15
Calcium carbonate, $CaO.CO_2$	89.04
Magnesium carbonate, $MgO.CO_2$	2.13
Manganese carbonate, $MnO.CO_2$	0.18
Water, hydroscopic, H_2O-	0.25
Organic matter	0.15
Unbalanced components (excess CO_2, H_2O)	-0.02
Total	100.09

The Putnam Hill limestone lies close below the summit of the flat-topped divide north of Munser Knob in Sections 22 and 15, Franklin Township. Just north of the Knob in Section 22, the limestone has been quarried for several years by Swartzentruber Brothers of Holmesville and Federicksburg and sold for agricultural use. The physical character of the limestone is given in the following description of exposures in the quarry.

	Ft.	In.
Glacial drift and weathered shale	8	0
Limestone, gray to bluish brown, dense, tends to split in layers 2 inches to 8 inches thick, Putnam Hill	5	6
Shale, gray to bluish gray	--	6
Coal, reported thickness, Brookville or No. 4	2	6

The five feet six inches of Putnam Hill limestone exposed in this quarry was sampled for chemical analysis by R. E. Lamborn on May 23, 1941.

Sample No. 338

Chemical analysis of Putnam Hill limestone from quarry of Swartzentruber Brothers, Section 22, Franklin Township, Wayne County, Downs Schaaf, analyst

	Per cent
Silica, SiO_2	1.80
Alumina, Al_2O_3	0.77
Ferric oxide, Fe_2O_3	0.08
Ferrous oxide, FeO	0.73
Iron disulphide, FeS_2	0.08
Magnesium oxide, MgO	0.99
Calcium oxide, CaO	52.27

Strontium oxide, SrO	<0.01
Barium oxide, BaO	<0.01
Sodium oxide, Na_2O	0.02
Potassium oxide, K_2O	0.11
Water, hydroscopic, H_2O-	0.19
Water, combined, H_2O+	0.20
Carbon dioxide, CO_2	42.45
Titanium dioxide, TiO_2	0.05
Phosphorus pentoxide, P_2O_5	0.15
Sulphur trioxide, SO_3	0.03
Manganous oxide, MnO	0.13
Carbon, organic, C	0.04
Hydrogen, organic, H	----
Total	100.09

The per cent of each of the compounds probably present has been computed (Lamborn) from the chemical analysis.

Hydrated silicates $(Na, K)_2O.3Al_2O_3.6SiO_2.2H_2O$	1.17
Hydrated silicates $Al_2O_3.2SiO_2.2H_2O$	0.80
Silica, SiO_2	0.89
Hydrated ferric oxide, $2Fe_2O_3.3H_2O$	0.09
Ferrous carbonate, $FeO.CO_2$	1.18
Iron disulphide, FeS_2	0.08
Titanium dioxide, TiO_2	0.05
Calcium phosphate, $3CaO.P_2O_5$	0.33
Calcium sulphate, $CaO.SO_3$	0.05
Calcium carbonate, $CaO.CO_2$	92.94
Magnesium carbonate, $MgO.CO_2$	2.05
Manganous carbonate, $MnO.CO_2$	0.21
Water, hydroscopic, H_2O-	0.19
Organic matter	0.04
Unbalanced components (lacking CO_2, H_2O)	+0.02
Total	100.09

SUMMARY TABLE SHOWING COMPOSITION OF LIMESTONES IN THE EASTERN HALF OF OHIO

Sample No.	County	Township	Section	Firm, Property Owner, Etc.	Exposure	System	Formation or Series	Member	Thickness Sampled Ft. In.	Sampled By	Date of Sampling
350	Athens	Ames	11	Along road	Outcrop	Pennsylvanian	Conemaugh	Ames	1-7	Wilber Stout	June 25, 1941
437	Athens	Lee	13	Fred Johnston property	Quarry	Pennsylvanian	Conemaugh	Brush Creek	5-8	R. E. Lamborn	July 13, 1944
383	Athens	Bern	32	Gilbert Baudinot property	Old quarry	Pennsylvanian	Monongahela	Fishpot	6-1	R. E. Lamborn	June 23, 1942
384	Athens	Rome	20	Starr Highway	Quarry	Pennsylvanian	Monongahela	Fishpot	5-3	R. E. Lamborn	June 23, 1942
369	Belmont	Flushing	8	Jesse Bethel property	Quarry	Pennsylvanian	Conemaugh	Pittsburgh	3-10	R. E. Lamborn	Aug. 8, 1941
368	Belmont	Warren	22	Campbell & Dew	Mine	Pennsylvanian	Monongahela	Fishpot	12-2	R. E. Lamborn	Aug. 7, 1941
366	Belmont	Wayne	23	Chalmer G. Kemp property	Old Quarry	Pennsylvanian	Monongahela	Fishpot	6-4	R. E. Lamborn	Aug. 7, 1941
419	Belmont	Washington	3	Along highway	Quarry	Pennsylvanian	Monongahela	Fishpot	2-8	R. E. Lamborn	Sept. 14, 1943
420	Belmont	Washington	4	Along highway	Quarry	Pennsylvanian	Monongahela	Fishpot	9-10	R. E. Lamborn	Sept. 14, 1943
425	Belmont	Pultney	12	Along highway	Outcrop	Pennsylvanian	Monongahela	Fishpot	5-5½	R. E. Lamborn	Sept 17, 1943
423	Belmont	Pultney	12	Along highway	Outcrop	Pennsylvanian	Monongahela	Fishpot	6-3	R. E. Lamborn	Sept 17, 1943
424	Belmont	Pultney	12	Along highway	Outcrop	Pennsylvanian	Monongahela	Fishpot	8-8	R. E. Lamborn	Sept 17, 1943
421	Belmont	Pease	36	Along Glenns Run	Outcrop	Pennsylvanian	Monongahela	Benwood	11-6	R. E. Lamborn	Sept. 16, 1943
422	Belmont	Richland	21	Along U. S. Route 40	Outcrop	Permian	Washington	Elm Grove	1-8	R. E. Lamborn	Sept. 16, 1943
365	Belmont	Pease	32	A. H. Pickens	Quarry	Permian	Washington	Washington	9-8½	R. E. Lamborn	Aug. 6, 1941
332	Carroll	Rose	36	Whitacre-Greer Fire proofing Co.	Pit	Pennsylvanian	Allegheny	Putnam Hill	2-5	R. E. Lamborn	May 20, 1951
360	Carroll	Fox	26	Lida Graham property	Old quarry	Pennsylvanian	Conemaugh	Ames	3-6	R. E. Lamborn	July 30, 1941
441	Columbiana	Salem	3	Salem Mining Company property	Coal mine	Pennsylvanian	Allegheny	Salem	0-8	M. T. Sturgeon	——
1000	Columbiana	Center	9	Ohio Cement Company	Old mine	Pennsylvanian	Allegheny	Lower Freeport	2-2	C. F. Moses	Aug. 22, 1921
1001	Columbiana	Center	25	Lisbon Lime Company	Old mine	Pennsylvanian	Allegheny	Upper Freeport		C. F. Moses	Aug. 22, 1921
1002	Columbiana	Madison	22	On Round Knob	Outcrop	Pennsylvanian	Conemaugh	Cambridge	2-11	C. F. Moses	Aug. 22, 1921
1003	Columbiana	Madison	21	Along road	Outcrop	Pennsylvanian	Conemaugh	Ames	2-1	C. F. Moses	Aug. 22, 1921
321	Coshocton	White Eyes		Along ravine	Outcrop	Pennsylvanian	Pottsville	Lower Mercer	5-6	R. E. Lamborn	Apr. 30, 1941
340	Coshocton	White Eyes	6	Boyd property	Quarry	Pennsylvanian	Pottsville	Lower Mercer	3-2	R. E. Lamborn	May 23, 1941
439	Coshocton	Clark	22	Along ravine	Outcrop	Pennsylvanian	Pottsville	Lower Mercer	4-3	R. E. Lamborn	Sept. 8, 1944
343	Coshocton	Jackson	15	Along road	Outcrop	Pennsylvanian	Pottsville	Lower Mercer	3-9	R. E. Lamborn	June 10, 1941
412	Coshocton	Virginia	15	Along ravine on Ralph Foster property	Outcrop	Pennsylvanian	Pottsville	Lower Mercer	3-7	R. E. Lamborn	July 28, 1943
342	Coshocton	Monroe	19	N. J. Markley property	Old quarry	Pennsylvanian	Allegheny	Putnam Hill	4-6	R. E. Lamborn	June 10, 1942
341	Coshocton	Perry	4	W. R. Speckman property	Old quarry	Pennsylvanian	Allegheny	Putnam Hill	13-2	R. E. Lamborn	June 9, 1941
402	Coshocton	Newcastle	13	Along highway	Outcrop	Pennsylvanian	Allegheny	Putnam Hill	8-4	R. E. Lamborn	July 26, 1943
322	Coshocton	Pike	10	Clyde Graham property	Quarry	Pennsylvanian	Allegheny	Putnam Hill	5-2	R. E. Lamborn	May 1, 1941
397	Gallia	Springfield	21	Ray Grover	Quarry	Pennsylvanian	Conemaugh	Brush Creek	4-1	R. E. Lamborn	Sept. 30, 1942
395	Gallia	Morgan	25	Ray Grover	Quarry	Pennsylvanian	Conemaugh	Cambridge	3-0	R. E. Lamborn	Sept. 18, 1942
398	Gallia	Perry	28	Miller Brothers	Quarry	Pennsylvanian	Conemaugh	Cambridge	2-9	R. E. Lamborn	Sept 30, 1942
357	Guernsey	Valley	13	One-half mile south of Bluebell	Old quarry	Pennsylvanian	Conemaugh	Ames	4-9	R. E. Lamborn	July 2, 1941
355	Guernsey	Wills	13	Maude Laughlin property	Old quarry	Pennsylvanian	Conemaugh	Summerfield	3-9	R. E. Lamborn	July 1, 1941
356	Guernsey	Oxford	11	H. A. Thompson	Quarry	Pennsylvanian	Conemaugh	Summerfield	7-9	R. E. Lamborn	July 1, 1941
432	Guernsey	Oxford	14	H. A. Thompson	Quarry	Pennsylvanian	Conemaugh	Summerfield	4-1	R. E. Lamborn	Oct. 7, 1943
438	Harrison	Franklin	32	J. B. Gladman Hrs. property	Outcrop	Pennsylvanian	Conemaugh	Ames	5-4	R. E. Lamborn	Aug. 22, 1944
406	Harrison	German	14	Oliver Monaco property	Drill core	Pennsylvanian	Conemaugh	Pittsburgh	6-10	R. E. Lamborn	1949
364	Harrison	Cadiz	3	J. B. Mallarnee property	Quarry	Pennsylvanian	Monongahela	Redstone	15-4	R. E. Lamborn	July 29, 1941
363	Harrison	Green	25	Boyd Wallace	Quarry	Pennsylvanian	Monongahela	Redstone	11-0	R. E. Lamborn	July 29, 1941
440	Harrison	Short Creek	25	Hanna Coal Company	Strip mine	Pennsylvanian	Monongahela	Fishpot	18-9	George White	1944
415	Hocking	Starr	23	At Union Furnace	Outcrop	Pennsylvanian	Pottsville	Lower Mercer	3-10	R. E. Lamborn	Aug. 12, 1943
330	Holmes	Knox		Nashville Lime & Stone Quarries Company	Quarry	Pennsylvanian	Allegheny	Putnam Hill	5-6	R. E. Lamborn	May 8, 1941
339	Holmes	Salt Creek	6	Andrew Swartzentruber	Quarry	Pennsylvanian	Allegheny	Putnam Hill	5-6	R. E. Lamborn	May 23, 1941
336	Holmes	Salt Creek	3	A. E. Mullett property	Quarry	Pennsylvanian	Allegheny	Putnam Hill	6-0	R. E. Lamborn	May 22, 1941
337	Holmes	Hardy	17	Kaser Brothers	Quarry	Pennsylvanian	Allegheny	Putnam Hill	5-0	R. E. Lamborn	May 21, 1941
411	Holmes	Hardy	18	Irvin Horner property	Quarry	Pennsylvanian	Allegheny	Putnam Hill	3-2	R. E. Lamborn	July 15, 1943
392	Jackson	Madison	29	Griff C. Jones property	Old quarry	Pennsylvanian	Allegheny	Vanport	5-0	R. E. Lamborn	Sept. 16, 1942
391	Jackson	Bloomfield	17	Iram Walton & Sons	Quarry	Pennsylvanian	Allegheny	Vanport	6-6	R. E. Lamborn	Sept. 16, 1942
361	Jefferson	Salem	33	R. B. Barnes property	Old quarry	Pennsylvanian	Conemaugh	Ames	6-8	R. E. Lamborn	July 30, 1941
362	Jefferson	Wayne	36	Tipton property	Old quarry	Pennsylvanian	Conemaugh	Ames	5-9	R. E. Lamborn	July 31, 1942
416	Lawrence	Upper	26	Alpha Portland Cement Company	Mine	Mississippian	Maxville		39-8	R. E. Lamborn	Sept. 1, 1943
394	Lawrence	Washington	23	Along Route 75	Outcrop	Pennsylvanian	Allegheny	Vanport	5-6	R. E. Lamborn	Sept. 17, 1942
393	Lawrence	Decatur	11	Buckeye Coal & Lime Company	Mine	Pennsylvanian	Allegheny	Vanport	4-6	R. E. Lamborn	Sept. 17, 1942
417	Lawrence	Decatur	32	Superior Portland Cement Company	Mine	Pennsylvanian	Allegheny	Vanport	1-4	R. E. Lamborn	Sept. 2, 1943
418	Lawrence	Decatur	32	Superior Portland Cement Company	Mine	Pennsylvanian	Allegheny	Vanport	5-8	R. E. Lamborn	Sept. 2, 1943
400	Lawrence	Elizabeth	16	Southern Ohio Products Company	Quarry	Pennsylvanian	Allegheny	Vanport	4-8	R. E. Lamborn	Oct. 2, 1942
399	Lawrence	Elizabeth	14	Stewart Lime Company	Mine	Pennsylvanian	Allegheny	Vanport	6-9	R. E. Lamborn	Oct. 1, 1942
407	Lawrence	Elizabeth	14	Stewart Lime Company	Mine	Pennsylvanian	Allegheny	Ferriferous ore	0-8	R. E. Lamborn	Oct. 1, 1942
235	Lawrence	Decatur	25	Along road at south edge of section	Old quarry	Pennsylvanian	Conemaugh	Brush Creek		Julian Maxey	Sept. 22, 1939
233	Lawrence	Mason	6	One-half mile northeast of Arabia	Quarry	Pennsylvanian	Conemaugh	Brush Creek		Julian Maxey	Sept. 8, 1939
232	Lawrence	Symmes	19	O. E. Irish & E. L. Riley property	Outcrop	Pennsylvanian	Conemaugh	Cambridge		Julian Maxey	Sept. 8, 1939
234	Lawrence	Mason	7	Near Arabia	Old quarry	Pennsylvanian	Conemaugh	Cambridge		Julian Maxey	Sept. 21, 1939
435	Licking	Hopewell		Along road three-fourths mile north of Hearst School	Outcrop	Pennsylvanian	Pottsville	Lower Mercer	5-8	R. E. Lamborn	June 29, 1944
83	Licking	Hopewell		Three miles north of Brownsville	Outcrop	Pennsylvanian	Allegheny	Vanport Flint	6-0	Wilber Stout	1934
409	Mahoning	Poland		Along Grindstone Run	Outcrop	Pennsylvanian	Pottsville	Lowellville	2-0	R. E. Lamborn	July 14, 1943
324	Mahoning	Berlin		Two miles northeast of North Benton	Old quarry	Pennsylvanian	Pottsville	Lower Mercer	2-9	R. E. Lamborn	May 6, 1941
328	Mahoning	Poland		Along Yellow Creek at Poland	Outcrop	Pennsylvanian	Pottsville	Lower Mercer	2-7½	R. E. Lamborn	May 7, 1941
325	Mahoning	Poland		Carbon Limestone Company	Quarry	Pennsylvanian	Allegheny	Vanport	19-8	R. E. Lamborn	May 6, 1941
326	Mahoning	Poland		Carbon Limestone Company	Old quarry	Pennsylvanian	Allegheny	Vanport	8-0	R. E. Lamborn	May 7, 1941
327	Mahoning	Poland		Carbon Limestone Company	Old quarry	Pennsylvanian	Allegheny	Vanport	5-0	R. E. Lamborn	May 7, 1941
396	Meigs	Salem	12	Meigs County	Old quarry	Pennsylvanian	Conemaugh	Cambridge	2-0	R. E. Lamborn	Sept. 29, 1942
389	Meigs	Scipio	12	R. E. Wilson	Old quarry	Pennsylvanian	Conemaugh	Pittsburgh	3-4	R. E. Lamborn	Sept. 10, 1942
387	Monroe	Wayne	1	Along Route 26	Outcrop	Pennsylvanian	Monongahela	Redstone	6-6	R. E. Lamborn	June 26, 1942
371	Monroe	Malaga	28	Kohrig & Ankron	Quarry	Pennsylvanian	Monongahela	Fishpot	11-2	R. E. Lamborn	Aug. 13, 1941
388	Monroe	Wayne	3	Clem Smithenberger	Quarry	Pennsylvanian	Monongahela	Fishpot ?	5-8	R. E. Lamborn	June 26, 1942
426	Monroe	Center	18	H. F. Zerger	Quarry	Pennsylvanian	Monongahela	Benwood (?)	4-3	R. E. Lamborn	Sept. 29, 1943
427	Monroe	Center	18	H. F. Zerger	Quarry	Pennsylvanian	Monongahela	Benwood (?)	2-0	R. E. Lamborn	Sept. 29, 1943
428	Monroe	Salem	7	Along Sunfish Creek	Outcrop	Pennsylvanian	Monongahela	Benwood (?)	4-6	R. E. Lamborn	Sept. 29, 1943
429	Monroe	Salem	7	Along Sunfish Creek	Outcrop	Pennsylvanian	Monongahela	Arnoldsburg (?)	8-4	R. E. Lamborn	Sept. 29, 1943
386	Monroe	Washington	19	Turner Hill	Quarry	Pennsylvanian	Monongahela	Benwood (?)	3-0	R. E. Lamborn	June 25, 1942
436	Morgan	Deerfield	15	Along Kickapoo Creek	Outcrop	Pennsylvanian	Conemaugh	Ames	2-0	R. E. Lamborn	July 11, 1944
375	Morgan	Bristol	7	Everitt Thurley property	Quarry	Pennsylvanian	Monongahela	Fishpot	6-7	R. E. Lamborn	June 9, 1942
376	Morgan	Meigsville	18	Harvey Archer property	Quarry	Pennsylvanian	Monongahela	Fishpot	5-4	R. E. Lamborn	June 10, 1942
352	Morgan	Union	33	William Wyner property	Old quarry	Pennsylvanian	Monongahela	Fishpot		Wilber Stout	June 25, 1941
353	Morgan	Union	33	William Wyner property	Old quarry	Pennsylvanian	Monongahela	Fishpot		Wilber Stout	June 25, 1941
377	Morgan	Windsor		Harry Daugherty	Quarry	Pennsylvanian	Monongahela	Benwood - Uniontown	7-0	R. E. Lamborn	June 10, 1942
345	Muskingum	Newton	18	Columbia Cement Division	Quarry	Mississippian	Maxville	—	17-9	R. E. Lamborn	June 12, 1941
346	Muskingum	Newton	18	Columbia Cement Division	Quarry	Mississippian	Maxville	—	6-5	R. E. Lamborn	June 12, 1941
347	Muskingum	Newton	18	Columbia Cement Division	Quarry	Mississippian	Maxville	—	2-0	R. E. Lamborn	June 12, 1941
348	Muskingum	Newton	18	Columbia Cement Division	Quarry	Mississippian	Maxville	—	2-1	R. E. Lamborn	June 12, 1941
349	Muskingum	Newton	18	Columbia Cement Division	Quarry	Mississippian	Maxville	—	5-9	R. E. Lamborn	June 12, 1941
354	Muskingum	Hopewell	15	Forbes Construction Company	Quarry	Mississippian	Maxville	—	5-3	R. E. Lamborn	June 31, 1941
442	Muskingum	Wayne	29	Margaret E. McCord property	Core	Mississippian	Maxville	—	7-8	C. H. Bowen	——
443	Muskingum	Wayne	29	Margaret E. McCord property	Core	Mississippian	Maxville	—	8-5	C. H. Bowen	——
444	Muskingum	Wayne	29	Margaret E. McCord property	Core	Mississippian	Maxville	—	11-2	C. H. Bowen	——
445	Muskingum	Wayne	29	Margaret E. McCord property	Core	Mississippian	Maxville	—	20-2	C. H. Bowen	——
446	Muskingum	Wayne	29	Margaret E. McCord property	Core	Mississippian	Maxville	—	5-4	C. H. Bowen	——
447	Muskingum	Wayne	29	Margaret E. McCord property	Core	Mississippian	Maxville	—	5-6	C. H. Bowen	——
1004	Muskingum	Muskingum	—	Along Beech Run	Outcrop	Pennsylvanian	Pottsville	Lower Mercer	4-0	Wilber Stout	1916
434	Muskingum	Jackson	7	Along road near Fairview School	Outcrop	Pennsylvanian	Pottsville	Lower Mercer	8-8	R. E. Lamborn	June 27, 1944
82	Muskingum	Hopewell	14	Harrison Drumm property	Outcrop	Pennsylvanian	Pottsville	Upper Mercer	1-0	R. A. Schoenlaub	1936
1005	Muskingum	Muskingum		Along Beech Run	Outcrop	Pennsylvanian	Allegheny	Putnam Hill	4-4	Wilber Stout	1916
403	Muskingum	Cass		One-half mile east of Elberson School	Outcrop	Pennsylvanian	Allegheny	Putnam Hill	4-1	R. E. Lamborn	July 29, 1943
404	Muskingum	Hopewell	5	James McQuigg property	Old quarry	Pennsylvanian	Allegheny	Vanport	6-0	R. E. Lamborn	Aug. 9, 1943
1006	Muskingum	Cass	—	Near Dutch School	Outcrop	Pennsylvanian	Allegheny	Vanport	4-0	Wilber Stout	1917
1007	Muskingum	Cass	14	Near Elberson School	Outcrop	Pennsylvanian	Allegheny	Hamden	3-0	Wilber Stout	1916
1008	Muskingum	Union	—	At New Concord	Outcrop	Pennsylvanian	Conemaugh	Cambridge	8-0	R. E. Lamborn	1917
344	Muskingum	Highland	24	J. A. Dixon property	Quarry	Pennsylvanian	Conemaugh	Cambridge	6-6	R. E. Lamborn	June 11, 1941
433	Muskingum	Highland	9	Along road three-fourths mile west of Bloomfield	Outcrop	Pennsylvanian	Conemaugh	Bloomfield	2-6	R. E. Lamborn	Oct. 8, 1943
1009	Muskingum	Union	10	Along road	Outcrop	Pennsylvanian	Conemaugh	Ames	1-8	———	1917
359	Muskingum	Meigs	2	Burlingham property	Quarry	Pennsylvanian	Monongahela	Fishpot	5-3	R. E. Lamborn	July 2, 1941
431	Noble	Noble	28	Along U. S. Route 21	Outcrop	Pennsylvanian	Conemaugh	Ewing	1-9	R. E. Lamborn	Oct. 6, 1943
372	Noble	Beaver	28	J. K. Shamhart property	Quarry	Pennsylvanian	Conemaugh	Summerfield	5-6	R. E. Lamborn	Aug. 13, 1941
430	Noble	Center	29	Along ravine	Outcrop	Pennsylvanian	Conemaugh	Summerfield	2-4	R. E. Lamborn	Oct. 1, 1941
373	Noble	Beaver	11	William Egan property	Quarry	Pennsylvanian	Monongahela	Fishpot	10-6	R. E. Lamborn	Aug. 14, 1941
367	Noble	Beaver	1	Mila Carpenter property	Quarry	Pennsylvanian	Monongahela	Fishpot	10-4	R. E. Lamborn	Aug. 7, 1941
370	Noble	Stock	29	Richard Colland property	Quarry	Pennsylvanian	Monongahela	Fishpot	11-0	R. E. Lamborn	Aug. 12, 1941
358	Noble	Brookfield	15	Charles R. Hamilton	Quarry	Pennsylvanian	Monongahela	Fishpot	5-3	R. E. Lamborn	July 2, 1941
380	Noble	Olive	12	Oscar King property	Quarry	Pennsylvanian	Monongahela	Fishpot	3-6	R. E. Lamborn	June 12, 1942
381	Noble	Olive	12	Oscar King property	Quarry	Pennsylvanian	Monongahela	Fishpot	7-2	R. E. Lamborn	June 12, 1942
374	Noble	Sharon	27	Along road west of Olive Green Creek	Old quarry	Pennsylvanian	Monongahela	Benwood	6-5	R. E. Lamborn	Aug. 15, 1941
382	Noble	Olive	32	B. W. Willey property	Quarry	Pennsylvanian	Monongahela	Benwood - Uniontown	13-6	R. E. Lamborn	June 12, 1942
379	Noble	Jackson	27	Along road	Old quarry	Pennsylvanian	Monongahela	Benwood	8-0	R. E. Lamborn	June 11, 1942
413	Perry	Reading	25	E. E. Venatta property	Old quarry	Mississippian	Maxville	—	7-8	R. E. Lamborn	Aug. 10, 1943
351	Perry	Monday Creek	20	Howdysell property	Old quarry	Mississippian	Maxville	—	6-9¼	Wilber Stout	June 25, 1941
414	Perry	Monday Creek	9	Along road	Outcrop	Pennsylvanian	Pottsville	Upper Mercer	3-0	R. E. Lamborn	Aug. 11, 1943
408	Portage	Atwater	—	Along Willow Run	Outcrop	Pennsylvanian	Pottsville	Lower Mercer	3-0	R. E. Lamborn	July 13, 1943
401	Stark	Lake	3	National Fireproofing Co. at Aultman	Pit	Pennsylvanian	Pottsville	Lower Mercer	1-9	R. E. Lamborn	July 12, 1943
410	Stark	Lawrence	18	V. H. Oser property	Outcrop	Pennsylvanian	Pottsville	Lower Mercer	1-8	R. E. Lamborn	July 15, 1943
323	Stark	Lake	29	Greentown Lime Company	Quarry	Pennsylvanian	Allegheny	Putnam Hill	4-9	R. E. Lamborn	May 5, 1941
329	Stark	Malboro	32	Diamond Portland Cement Company	Quarry	Pennsylvanian	Allegheny	Putnam Hill	8-7	R. E. Lamborn	May 8, 1941
334	Stark	Canton	35	Near abandoned mine	Outcrop	Pennsylvanian	Allegheny	Putnam Hill	3-0	R. E. Lamborn	May 2, 1941
331	Stark	Pike	27	Sparta Ceramic Company	Pit	Pennsylvanian	Allegheny	Putnam Hill	3-0	R. E. Lamborn	May 19, 1941
333	Stark	Pike	8	Homer Bradley property	Mine	Pennsylvanian	Allegheny	Putnam Hill	4-0	R. E. Lamborn	May 20, 1941
319	Stark	Bethlehem	20	Zimmerman Brothers	Pit	Pennsylvanian	Allegheny	Putnam Hill	2-8	R. E. Lamborn	April 29, 1941
1010	Tuscarawas	Lawrence	—	Zoar Agricultural Lime Company	Quarry	Pennsylvanian	Pottsville	Upper Mercer	4-0	E. J. Bognar	1926
1011	Tuscarawas	Sandy	—	South of west of Mineral City	Old quarry	Pennsylvanian	Allegheny	Putnam Hill	— —	E. J. Bognar	1926
318	Tuscarawas	Dover	—	L. H. Rennert & Sons	Quarry	Pennsylvanian	Allegheny	Vanport	3-8	R. E. Lamborn	April 28, 1941
320	Tuscarawas	Sugar Creek	—	A. J. Slabach	Quarry	Pennsylvanian	Allegheny	Vanport	6-2	R. E. Lamborn	April 29, 1941
317	Tuscarawas	Bucks	11	Harry R. King property	Quarry	Pennsylvanian	Allegheny	Vanport	2-6	R. E. Lamborn	April 28, 1941
81	Vinton	Elk	14	————	Outcrop	Pennsylvanian	Allegheny	Zaleski	3-2	R. A. Schoenlaub	1936
1012	Vinton	Elk	30	Charles Dayton property	Old quarry	Pennsylvanian	Allegheny	Vanport	6-0	Wilber Stout	1922
1013	Vinton	Elk	36	Vinton Furnace tract	Old quarry	Pennsylvanian	Allegheny	Vanport	8-0	Wilber Stout	1922
80	Vinton	Clinton	27	Puritan Brick Company property	Outcrop	Pennsylvanian	Allegheny	Vanport	6-10	Wilber Stout	Oct. 23, 1935
390	Vinton	Wilkesville	28	Clarion Lime Company	Quarry	Pennsylvanian	Allegheny	Vanport	6-11	R. E. Lamborn	Sept. 15, 1942
385	Washington	Liberty	14	Along Sycamore Fork	Outcrop	Pennsylvanian	Monongahela	Redstone	5-9	R. E. Lamborn	June 24, 1942
378	Washington	Waterford	—	Waterford Quarries Company	Quarry	Pennsylvanian	Monongahela	Benwood - Uniontown	7-11	R. E. Lamborn	June 11, 1942
405	Washington	Wesley	26	E. L. Waite property	Old quarry	Pennsylvanian	Monongahela	Benwood - Uniontown	3-10	R. E. Lamborn	July 25, 1946
335	Wayne	Paint	24	Clinton M. Harrold property	Old quarry	Pennsylvanian	Allegheny	Putnam Hill	3-2	R. E. Lamborn	May 21, 1941
338	Wayne	Franklin	22	Swartzentruber Brothers	Quarry	Pennsylvanian	Allegheny	Putnam Hill	5-6	R. E. Lamborn	May 23, 1941

CHEMICAL ANALYSIS

Sample No.	Silica, SiO_2	Alumina, Al_2O_3	Ferric, Fe_2O_3	Ferrous, FeO	Iron disulfide, FeS_2	Magnesium oxide, MgO	Calcium oxide, CaO	Strontium oxide, SrO	Barium oxide, BaO	Sodium oxide, Na_2O	Potassium oxide, K_2O	Water, hygroscopic, H_2O-	Water, combined, H_2O+	Carbon dioxide, CO_2	Titanium dioxide, TiO_2	Phosphorus pentoxide, P_2O_5	Sulphur trioxide, SO_3	Manganese oxide, MnO	Carbon, organic, C	Hydrogen, organic, H	Total	Analyst
350	3.11	0.27	0.03	0.47	0.03	0.40	52.40	<0.01	<0.01	<0.01	0.01	0.18	0.06	42.08	0.04	0.21	0.07	0.77	0.02	.....	100.15	Downs Schaaf
437	38.38	2.19	0.19	0.71	0.04	0.49	31.10	.....	.....	0.37	0.18	0.31	0.86	24.68	0.13	0.16	0.04	0.17	.....	.....	100.00	E. Chadbourn
383	7.02	1.76	0.53	0.67	<0.01	1.46	47.55	<0.01	0.20	0.16	0.11	0.12	0.35	38.88	0.06	0.32	0.12	0.03	0.67	0.08	100.09	Nalin Labs.
384	5.73	1.48	0.80	0.59	<0.01	0.93	49.09	<0.01	0.08	0.19	0.22	0.10	0.23	39.81	0.10	0.04	0.16	0.03	0.55	0.05	100.18	Nalin Labs.
369	5.75	1.01	0.05	3.40	0.14	7.63	39.42	<0.01	<0.01	0.02	0.06	0.07	0.30	41.15	0.12	0.14	0.48	0.38	0.02	.....	100.14	Downs Schaaf
368	12.98	3.30	0.03	1.90	0.20	10.65	31.01	<0.01	<0.01	0.15	0.60	0.78	0.95	37.00	0.20	0.12	0.06	0.12	0.02	.....	100.07	Downs Schaaf
366	7.00	1.95	0.03	1.11	0.18	7.41	40.30	<0.01	<0.01	0.05	0.16	0.53	0.60	40.33	0.11	0.11	0.06	0.17	0.07	.....	100.17	Downs Schaaf
419	6.23	0.84	0.05	0.99	0.17	4.71	45.00	.....	.....	0.05	0.18	0.08	0.56	40.62	0.02	0.02	0.02	0.06	.....	.....	99.60	E. Chadbourn
420	9.55	2.56	0.21	1.09	0.45	6.86	38.88	.....	.....	0.13	0.56	0.26	0.98	37.82	0.10	0.06	0.04	0.07	.....	.....	99.62	E. Chadbourn
425	11.15	1.91	0.25	0.68	0.26	5.30	40.80	.....	.....	0.08	0.33	0.20	0.97	37.34	0.06	0.06	0.10	0.07	.....	.....	99.56	E. Chadbourn
423	14.51	3.76	0.19	1.87	0.54	12.75	27.46	.....	.....	0.26	0.83	0.49	1.30	35.46	0.16	0.08	0.08	0.08	.....	.....	99.82	E. Chadbourn
424	10.23	1.67	0.04	1.58	0.17	6.81	38.96	.....	.....	0.14	0.26	0.19	0.82	38.44	0.07	0.07	0.05	0.09	.....	.....	99.59	E. Chadbourn
421	22.03	4.42	0.61	1.15	0.32	9.30	27.75	.....	.....	0.17	1.12	0.61	1.56	30.42	0.20	0.08	0.01	0.06	.....	.....	99.81	E. Chadbourn
422	5.93	0.85	0.11	1.05	0.99	0.57	49.19	.....	.....	0.08	0.00	0.08	0.67	39.46	0.01	0.08	0.07	0.45	.....	.....	99.59	E. Chadbourn
365	4.82	0.86	0.02	0.70	0.03	0.75	50.86	<0.01	<0.01	0.02	0.08	0.29	0.25	41.09	0.07	0.12	0.02	0.11	0.08	.....	100.17	Downs Schaaf
332	5.34	2.20	0.02	0.93	0.47	1.07	48.70	<0.01	<0.01	0.03	0.10	0.22	0.59	39.88	0.10	0.18	0.03	0.20	0.03	.....	100.09	Downs Schaaf
360	6.50	1.18	0.02	0.38	0.08	0.74	49.84	<0.01	<0.01	0.03	0.10	0.23	0.29	40.10	0.05	0.15	0.09	0.25	0.02	.....	100.05	Downs Schaaf
441	4.07	2.39	1.90	11.57	<0.01	3.66	37.08	<0.01	<0.01	0.22	0.35	0.18	0.05	36.70	0.04	0.32	0.14	0.30	1.11	0.21	100.29	Nalin Labs.
1000	13.80	7.00	4.55	.....	.....	1.32	38.35	.....	.....	2.61	0.86	.....	.....	.....	.....	0.248	none	0.29	.....	.....	....	D. J. Demorest
1001	15.40	4.47	1.99	.....	.....	0.91	42.10	.....	.....	0.22	0.52	.....	.....	.....	.....	0.139	none	0.11	.....	.....	....	D. J. Demorest
1002	6.20	2.39	1.34	.....	.....	0.91	49.50	.....	.....	.....	.....	.....	.....	.....	.....	0.217	none	0.39	.....	.....	....	D. J. Demorest
1003	3.90	1.34	1.82	.....	.....	0.87	51.00	.....	.....	.....	.....	.....	.....	.....	.....	0.093	0.426	0.439	.....	.....	....	D. J. Demorest
321	4.59	1.25	0.02	0.86	0.16	1.10	49.92	<0.01	<0.01	0.02	0.05	0.19	0.35	40.61	0.05	0.28	0.18	0.14	0.27	0.02	100.06	Downs Schaaf
340	3.11	1.40	0.02	1.55	0.23	1.14	49.95	<0.01	<0.01	0.02	0.10	0.24	0.40	41.36	0.07	0.07	0.09	0.19	0.07	.....	100.01	Downs Schaaf
439	2.38	0.54	0.38	0.94	0.24	0.87	51.44	.....	.....	0.07	0.12	0.08	0.76	41.28	0.02	0.20	0.12	0.12	.....	.....	99.56	E. Chadbourn
343	2.68	1.01	0.03	1.05	0.19	0.92	51.31	<0.01	<0.01	<0.01	0.01	0.18	0.29	41.80	0.05	0.15	0.06	0.16	0.12	0.01	100.02	Downs Schaaf
412	3.28	1.09	0.21	0.85	0.32	0.85	50.95	.....	.....	0.08	0.22	0.13	0.57	40.80	0.05	0.19	0.12	0.12	.....	.....	99.83	E. Chadbourn
342	2.21	0.70	0.03	0.65	0.12	0.90	52.30	<0.01	<0.01	<0.01	0.02	0.14	0.18	42.34	0.06	0.12	0.03	0.14	0.09	.....	100.03	Downs Schaaf
341	2.61	0.55	0.02	0.64	0.06	0.75	52.50	<0.01	<0.01	<0.01	0.01	0.14	0.15	42.33	0.06	0.10	0.01	0.07	0.07	.....	100.07	Downs Schaaf
402	2.71	1.00	0.29	0.68	0.24	0.76	51.68	.....	.....	0.04	0.16	0.05	0.45	41.66	0.03	0.06	0.12	0.07	.....	.....	100.00	E. Chadbourn
322	1.95	0.44	0.02	0.50	0.15	0.86	52.82	<0.01	<0.01	0.01	0.02	0.11	0.11	42.61	0.03	0.10	0.04	0.10	0.15	0.01	100.03	Downs Schaaf
397	45.00	6.40	0.63	0.58	<0.01	0.49	22.98	<0.01	<0.01	0.25	0.48	0.18	1.35	21.30	0.02	0.03	0.06	0.01	0.34	0.06	100.16	Nalin Labs.
395	5.11	0.26	0.20	0.67	<0.01	0.70	51.26	<0.01	<0.01	0.10	0.16	0.05	0.03	41.27	0.02	0.02	0.24	0.03	0.18	0.02	100.32	Nalin Labs.
398	11.70	1.71	0.27	0.62	<0.01	0.80	45.46	<0.01	<0.01	0.08	0.16	0.07	0.57	38.04	<0.01	0.03	0.19	0.03	0.13	0.02	99.89	Nalin Labs.
357	4.77	1.48	0.04	2.02	0.30	0.75	48.68	<0.01	<0.01	0.03	0.11	0.28	0.38	40.47	0.04	0.10	0.06	0.60	0.02	.....	100.13	Downs Schaaf
355	2.20	0.06	0.02	0.32	<0.01	0.92	52.95	<0.01	<0.01	<0.01	0.01	0.22	0.02	42.88	0.01	0.03	0.07	0.33	0.03	.....	100.07	Downs Schaaf
356	2.72	0.14	0.02	0.49	<0.01	0.47	52.99	<0.01	<0.01	<0.01	0.01	0.21	0.04	42.50	0.01	0.06	0.02	0.29	0.03	.....	100.00	Downs Schaaf
432	5.28	0.67	0.02	1.40	0.49	2.34	48.08	.....	.....	0.04	0.05	0.08	0.45	40.76	0.02	0.08	0.03	0.28	.....	.....	100.07	E. Chadbourn
438	6.84	1.51	0.24	0.78	0.21	0.82	48.80	.....	.....	0.10	0.29	0.19	0.62	38.84	0.05	0.18	0.12	0.25	.....	.....	99.84	E. Chadbourn
406	5.51	1.26	0.07	1.29	0.28	0.81	49.39	.....	.....	0.07	0.17	0.04	0.58	40.27	0.05	0.09	0.04	0.30	.....	.....	100.22	E. Chadbourn
364	14.63	4.20	0.03	0.95	0.01	1.25	41.40	<0.01	<0.01	0.16	0.64	0.93	0.95	34.29	0.22	0.18	0.06	0.11	0.02	.....	100.03	Downs Schaaf
363	11.28	3.44	0.06	1.88	0.07	5.45	38.30	<0.01	<0.01	0.11	0.49	0.72	0.65	36.95	0.15	0.18	0.15	0.13	0.01	.....	100.02	Downs Schaaf
440	14.00	3.19	0.93	1.48	0.21	7.67	34.25	.....	.....	0.16	0.76	0.40	1.28	35.00	0.13	0.07	0.08	0.10	.....	.....	99.71	E. Chadbourn
415	55.18	5.73	0.45	1.08	0.88	0.73	17.74	.....	.....	0.20	1.14	0.30	1.76	14.06	0.23	0.20	0.16	0.08	.....	.....	99.92	E. Chadbourn
330	2.59	0.83	0.03	0.83	0.09	0.95	51.81	<0.01	<0.01	0.02	0.04	0.12	0.23	42.08	0.05	0.14	0.03	0.09	0.10	0.01	100.04	Downs Schaaf
339	2.44	0.88	0.02	0.70	0.11	1.02	51.80	<0.01	<0.01	0.03	0.10	0.22	0.25	41.98	0.06	0.21	0.05	0.07	0.09	.....	100.03	Downs Schaaf
336	2.17	0.68	0.02	0.74	0.02	0.98	52.21	<0.01	<0.01	<0.01	0.02	0.20	0.22	42.47	0.04	0.10	0.04	0.18	0.02	.....	100.11	Downs Schaaf
337	1.82	0.88	0.08	0.74	0.14	0.95	52.21	<0.01	<0.01	0.02	0.09	0.15	0.23	42.35	0.06	0.16	0.06	0.14	0.05	.....	100.13	Downs Schaaf
411	3.03	0.90	0.27	0.56	0.24	0.91	51.65	.....	.....	0.06	0.15	0.06	0.42	41.41	0.05	0.06	0.13	0.10	.....	.....	100.00	E. Chadbourn
392	0.93	0.11	0.14	0.99	<0.01	0.63	53.64	<0.01	<0.01	0.06	0.17	0.07	0.02	42.46	<0.01	0.14	0.83	<0.01	0.09	<0.01	100.28	Nalin Labs.
391	1.14	0.37	1.29	0.63	<0.01	0.77	51.56	<0.01	<0.01	0.09	0.24	0.09	<0.01	42.38	<0.01	0.11	1.25	<0.01	0.42	0.05	100.40	Nalin Labs.
361	5.11	1.58	0.03	1.17	0.03	0.90	49.30	<0.01	<0.01	0.02	0.06	0.45	0.40	40.36	0.05	0.16	0.07	0.31	0.02	.....	100.02	Downs Schaaf
362	9.35	1.55	0.02	0.81	0.02	0.92	47.32	<0.01	<0.01	0.02	0.08	0.48	0.36	38.61	0.05	0.15	0.06	0.25	0.02	.....	100.07	Downs Schaaf
416	8.84	1.47	0.75	0.62	0.21	2.68	45.54	.....	.....	0.07	0.55	0.15	0.59	38.26	0.12	0.02	0.08	0.03	.....	.....	99.98	E. Chadbourn
394	0.67	0.36	0.56	0.71	<0.01	0.60	53.13	<0.01	<0.01	0.05	0.20	0.05	<0.01	43.42	0.01	0.07	0.32	<0.01	0.09	0.01	100.25	Nalin Labs.
393	0.78	0.44	1.31	0.61	<0.01	0.65	51.55	<0.01	<0.01	0.08	0.22	0.10	0.04	42.43	0.01	0.10	1.28	<0.01	0.50	0.04	100.14	Nalin Labs.
417	1.36	0.27	0.04	0.92	0.24	0.32	53.43	.....	.....	0.04	0.06	0.08	0.21	42.45	0.02	0.19	0.11	0.15	.....	.....	99.89	E. Chadbourn
418	0.66	0.25	0.00	0.63	0.24	0.37	54.01	.....	.....	0.00	0.01	0.04	0.29	42.70	0.00	0.10	0.23	0.12	.....	.....	99.65	E. Chadbourn
400	0.81	0.20	0.24	0.57	<0.01	0.67	52.12	<0.01	<0.01	0.01	0.04	0.03	1.75	43.42	0.00	0.08	0.06	<0.01	0.13	0.02	100.15	Nalin Labs.
399	4.60	0.19	0.64	1.93	<0.01	0.77	48.21	<0.01	<0.01	0.03	0.05	0.00	1.82	41.11	0.01	0.10	0.21	0.01	0.19	0.05	99.92	Nalin Labs.
407	1.54	0.88	1.51	45.55	0.39	0.96	9.43	.....	.....	0.03	0.11	0.11	1.10	36.37	0.04	0.52	0.04	0.91	.....	.....	99.49	E. Chadbourn
235	51.20	4.60	0.77	1.07	0.20	0.75	20.71	<0.01	<0.01	0.10	0.74	0.97	1.06	17.30	0.14	0.25	0.02	0.15	0.04	.....	100.07	Downs Schaaf
233	52.75	6.28	0.59	1.01	<0.01	0.92	18.60	<0.01	<0.01	0.12	0.95	1.11	1.46	15.51	0.22	0.32	0.04	0.18	0.05	.....	100.11	Downs Schaaf
232	32.55	2.41	0.48	0.68	<0.01	0.79	33.51	<0.01	<0.01	0.01	0.02	0.60	0.72	27.40	0.16	0.29	0.04	0.34	0.07	.....	100.07	Downs Schaaf
234	23.50	1.83	0.35	0.72	0.65	0.90	38.55	<0.01	<0.01	0.07	0.35	0.60	0.36	31.37	0.06	0.21	0.04	0.41	0.08	.....	100.05	Downs Schaaf
435	30.46	4.31	0.49	1.08	0.86	0.90	32.45	.....	.....	0.14	0.94	0.34	1.46	25.74	0.14	0.23	0.08	0.09	.....	.....	99.71	E. Chadbourn
83	98.93	0.14	0.06	0.08	None	0.02	0.04	.....	.....	<0.01	<0.01	0.27	0.17	0.02	0.005	<0.01	None	<0.01	0.18	.....	99.915	Downs Schaaf
409	19.68	5.90	0.31	1.35	2.36	0.99	35.50	.....	.....	0.12	0.96	0.18	1.94	28.54	0.32	0.38	0.24	0.25	.....	.....	99.02	E. Chadbourn
324	1.77	1.14	0.03	1.07	0.61	1.01	51.28	<0.01	<0.01	0.02	0.05	0.16	0.33	41.81	0.06	0.18	0.11	0.14	0.25	0.02	100.04	Downs Schaaf
328	3.27	1.47	0.03	1.17	0.32	0.90	50.27	<0.01	<0.01	0.02	0.04	0.10	0.42	40.91	0.07	0.28	0.05	0.14	0.44	0.04	99.94	Downs Schaaf
325	2.40	0.40	0.02	0.55	0.03	0.53	52.92	<0.01	<0.01	0.01	0.02	0.12	0.10	42.31	0.03	0.16	0.07	0.12	0.21	0.02	100.02	Downs Schaaf
326	3.11	0.75	0.02	0.60	0.04	0.65	52.10	<0.01	<0.01	<0.01	0.01	0.10	0.20	41.82	0.06	0.14	0.08	0.10	0.24	0.02	100.04	Downs Schaaf
327	2.28	0.36	0.03	0.64	0.08	0.60	53.03	<0.01	<0.01	<0.01	0.02	0.08	0.09	42.59	0.03	0.11	0.03	0.10	0.02	.....	100.09	Downs Schaaf
396	3.80	0.95	0.40	0.36	0.01	0.75	50.06	<0.01	<0.01	0.08	0.14	0.08	0.41	42.48	0.01	0.10	0.13	0.03	0.17	0.03	99.98	Nalin Labs.
389	9.65	2.66	0.60	0.71	0.01	0.78	46.58	<0.01	0.15	0.12	0.05	0.38	0.29	36.99	0.15	0.19	0.31	0.02	0.47	0.05	100.15	Nalin Labs.
387	9.61	1.74	0.60	0.76	<0.01	1.43	45.48	<0.01	0.15	0.18	0.23	0.42	0.57	37.24	0.15	0.05	0.07	0.01	1.21	0.17	100.07	Nalin Labs.
371	10.72	2.15	0.03	0.88	0.12	5.70	40.04	<0.01	<0.01	0.05	0.30	0.68	0.66	38.16	0.14	0.11	0.03	0.20	0.08	.....	100.05	Downs Schaaf
388	17.38	5.30	1.42	1.18	<0.01	8.83	28.80	<0.01	0.18	0.24	0.42	0.59	1.45	33.22	0.23	0.08	0.03	0.04	0.54	0.08	100.01	Nalin Labs.
426	14.33	2.92	0.36	1.52	0.07	14.49	26.83	.....	.....	0.15	0.75	0.25	1.20	36.60	0.11	0.07	0.04	0.11	.....	.....	99.80	E. Chadbourn
427	8.88	2.47	0.24	0.54	0.06	1.44	46.69	.....	.....	0.09	0.54	0.23	0.80	37.32	0.10	0.08	0.02	0.08	.....	.....	99.58	E. Chadbourn
428	15.75	2.23	0.22	1.53	0.07	14.65	26.58	.....	.....	0.14	0.47	0.33	0.97	36.74	0.09	0.05	0.03	0.10	.....	.....	99.95	E. Chadbourn
429	18.73	3.94	0.70	1.56	0.06	7.49	32.05	.....	.....	0.15	0.76	0.43	1.53	32.12	0.20	0.05	0.03	0.10	.....	.....	99.90	E. Chadbourn
386	4.51	1.42	0.29	0.54	<0.01	1.96	49.24	<0.01	0.11	0.21	0.15	0.08	0.38	40.91	0.08	0.01	None	0.01	0.39	0.04	100.33	Nalin Labs.
436	6.53	1.00	0.41	0.59	0.04	0.47	49.83	.....	.....	0.14	0.09	0.06	0.41	39.48	0.05	0.34	0.07	0.53	.....	.....	100.04	E. Chadbourn
375	12.71	2.73	0.45	1.97	<0.01	5.63	37.56	0.05	0.20	0.02	<0.01	0.30	1.85	35.42	0.02	0.04	0.40	0.21	0.43	0.06	100.05	Nalin Labs.
376	8.28	2.05	0.04	0.86	<0.01	4.40	43.84	<0.01	0.09	0.02	<0.01	0.27	1.17	38.33	0.01	0.05	0.07	0.13	0.42	0.05	100.08	Nalin Labs.
352	9.20	1.95	0.29	0.25	0.03	0.79	47.40	<0.01	<0.01	0.02	0.07	1.10	0.45	38.12	0.14	0.10	0.03	0.11	0.04	.....	100.09	Downs Schaaf
353	9.65	2.25	0.28	0.26	0.04	0.77	46.88	<0.01	<0.01	0.03	0.11	1.16	0.50	37.70	0.14	0.09	0.05	0.11	0.03	.....	100.05	Downs Schaaf
377	10.59	2.51	0.33	0.50	<0.01	7.06	39.95	<0.01	0.10	0.02	<0.01	0.27	0.60	37.07	0.02	0.07	0.55	0.09	0.36	0.04	100.13	Nalin Labs.
345	1.65	0.35	0.02	0.30	0.12	0.40	53.90	<0.01	<0.01	0.02	0.07	0.09	0.07	42.88	0.03	0.06	0.03	0.07	0.02	.....	100.08	Downs Schaaf
346	4.82	1.05	0.02	0.47	0.14	0.75	50.88	<0.01	<0.01	0.03	0.14	0.25	0.27	40.95	0.10	0.05	0.05	0.05	0.04	.....	100.06	Downs Schaaf
347	11.40	1.95	0.02	0.44	0.05	1.10	45.75	<0.01	<0.01	0.05	0.29	0.70	0.61	37.17	0.12	0.16	0.10	0.06	0.06	.....	100.03	Downs Schaaf
348	73.70	1.02	0.02	0.42	0.01	0.55	12.75	<0.01	<0.01	<0.01	0.02	0.25	0.25	10.80	0.05	0.09	0.02	0.05	0.03	.....	100.02	Downs Schaaf
349	13.82	3.11	0.02	2.45	0.05	15.82	24.50	<0.01	<0.01	0.05	0.28	0.55	0.95	37.90	0.12	0.07	0.15	0.12	0.05	.....	100.01	Downs Schaaf
354	5.29	1.70	0.02	0.77	0.10	2.90	47.18	<0.01	<0.01	0.04	0.24	0.24	0.49	40.55	0.07	0.07	0.17	0.14	0.03	.....	100.00	Downs Schaaf
442	5.73	1.09	0.23	2.40	0.04	16.76	29.59	.....	.....	0.22	0.35	0.05	0.22	42.65	0.06	0.03	0.14	0.17	.....	.....	99.73	E. Chadbourn
443	11.03	2.54	0.20	0.81	0.19	2.47	43.88	.....	.....	0.11	0.60	0.15	0.63	37.04	0.14	0.01	0.08	0.04	.....	.....	99.92	E. Chadbourn
444	4.60	1.19	0.06	0.50	0.07	2.02	49.68	.....	.....	0.12	0.28	0.08	0.41	40.97	0.07	0.01	0.10	0.03	.....	.....	100.19	E. Chadbourn
445	4.58	1.17	0.11	0.45	0.04	1.48	50.50	.....	.....	0.06	0.28	0.05	0.27	40.99	0.06	0.05	0.05	0.04	.....	.....	100.18	E. Chadbourn
446	9.59	1.11	0.28	1.08	0.04	4.26	43.50	.....	.....	0.24	0.07	0.10	0.22	39.11	0.06	0.03	0.08	0.10	.....	.....	99.87	E. Chadbourn
447	19.19	3.00	0.26	2.95	0.82	2.94	35.64	——	——	0.16	0.59	0.24	0.97	32.29	0.21	0.14	0.15	0.26	.....	.....	99.81	E. Chadbourn
1004	8.59	1.50	1.59	.....	.....	2.12*	83.36**	.....	.....	.....	.....	.....	.....	.....	0.05	0.25	S 0.75	.....	.....	.....	98.21	D. J. Demorest
434	47.73	3.28	0.81	0.63	0.09	0.46	24.55	.....	.....	0.06	0.63	0.26	1.25	19.32	0.10	0.20	0.04	0.05	.....	.....	99.46	E. Chadbourn
82	95.33	0.29	1.01	1.14	0.05	0.01	0.40	.....	.....	0.05	0.09	0.27	0.44	0.74	0.02	0.14	<0.01	0.04	0.22	0.03	100.27	Downs Schaaf
1005	2.25	0.97	1.10	.....	.....	2.04*	92.32**	.....	.....	.....	.....	.....	.....	.....	0.05	0.07	S 0.16	.....	.....	.....	98.96	D. J. Demorest
403	1.89	0.64	0.24	0.62	0.24	0.78	52.40	.....	.....	0.05	0.13	0.09	0.33	42.21	0.03	0.05	0.08	0.12	.....	.....	99.90	E. Chadbourn
404	42.05	3.24	0.54	0.60	0.07	0.41	28.40	.....	.....	0.24	0.61	0.16	0.87	22.44	0.17	0.12	0.03	0.10	.....	.....	100.05	E. Chadbourn
1006	1.59	0.55	1.05	.....	.....	0.54	53.90	.....	.....	.....	.....	.....	.....	.....	Trace	P 0.059	S 0.25	.....	.....	.....	....	D. J. Demorest
1007	1.86	0.52	0.82	.....	.....	0.76	53.68	.....	.....	.....	.....	.....	.....	.....	Trace	P 0.039	S 0.15	.....	.....	.....	....	D. J. Demorest
1008	33.75	4.01	2.23	.....	.....	0.78	31.61	.....	.....	.....	.....	.....	.....	.....	0.22	P 0.059	S 0.079	.....	.....	.....	....	D. J. Demorest
344	44.72	1.07	0.02	0.53	0.08	0.33	28.72	<0.01	<0.01	0.02	0.09	0.45	0.30	23.24	0.07	0.09	0.04	0.19	0.04	.....	100.00	Downs Schaaf
433	3.69	0.50	0.14	0.56	0.26	0.37	51.85	.....	.....	0.04	0.06	0.06	0.49	41.14	0.01	0.02	0.09	0.43	.....	.....	99.71	E. Chadbourn
1009	4.77	1.83	6.34	.....	.....	1.45	46.28	.....	.....	.....	.....	.....	.....	....	0.10	P 0.18	S 0.14	.....	.....	.....	....	D. J. Demorest
359	5.88	1.40	0.04	0.74	0.10	4.07	45.75	<0.01	<0.01	0.02	0.07	0.45	0.38	40.80	0.06	0.05	0.07	0.14	0.04	.....	100.06	Downs Schaaf
431	2.68	1.00	0.26	0.40	0.07	0.39	52.50	.....	.....	0.01	0.11	0.14	0.48	41.56	0.03	0.08	0.02	0.33	.....	.....	100.06	E. Chadbourn
372	4.82	0.66	0.03	0.86	0.06	3.50	47.44	<0.01	<0.01	0.02	0.08	0.16	0.20	41.68	0.07	0.05	0.04	0.28	0.07	.....	100.00	Downs Schaaf
430	1.44	0.47	0.00	0.32	0.13	0.55	53.74	.....	.....	0.04	0.04	0.08	0.35	42.60	0.01	0.02	0.03	0.17	.....	.....	99.99	E. Chadbourn
373	10.02	3.03	0.03	0.88	0.44	5.60	39.80	<0.01	<0.01	0.07	0.40	0.50	0.95	37.84	0.14	0.08	0.05	0.16	0.05	.....	100.04	Downs Schaaf
367	9.61	1.55	0.02	0.95	0.15	5.83	40.92	<0.01	<0.01	0.08	0.34	0.71	0.29	38.95	0.12	0.14	0.05	0.14	0.15	0.02	100.02	Downs Schaaf
370	10.47	2.44	0.03	1.08	0.06	5.45	40.18	<0.01	<0.01	0.06	0.30	0.54	0.77	38.14	0.13	0.08	0.02	0.19	0.06	......	100.00	Downs Schaaf
358	7.65	1.42	0.03	0.88	0.40	5.29	42.60	<0.01	<0.01	0.07	0.28	0.80	0.42	39.75	0.09	0.05	0.07	0.18	0.06	......	100.04	Downs Schaaf
380	23.26	5.92	0.38	2.57	<0.01	10.22	22.92	<0.01	0.13	0.04	0.16	0.38	4.19	28.88	0.02	0.02	0.65	0.17	0.11	0.01	100.03	Nalin Labs.
381	11.43	3.09	0.74	0.95	<0.01	5.71	38.88	<0.01	0.06	0.22	0.44	0.43	0.38	36.64	0.14	0.22	0.14	0.02	0.55	0.06	100.10	Nalin Labs.
374	8.08	2.72	0.02	0.42	0.04	3.59	44.48	<0.01	<0.01	0.02	0.10	0.49	0.75	39.04	0.08	0.06	0.02	0.12	0.02	......	100.05	Downs Schaaf
382	12.47	2.35	1.00	0.65	<0.01	6.35	38.88	<0.01	0.14	0.25	0.10	0.36	0.57	36.11	0.08	0.19	0.09	0.01	0.50	0.06	100.16	Nalin Labs.
379	15.46	3.53	0.45	0.81	<0.01	5.94	36.93	<0.01	0.08	0.03	0.01	0.39	0.95	34.13	0.01	0.04	0.21	0.05	1.01	0.16	100.19	Nalin Labs.
413	7.83	1.77	0.20	1.91	0.19	5.73	41.45	.....	.....	0.04	0.40	0.11	0.55	39.31	0.09	0.04	0.13	0.12	......	......	99.87	E. Chadbourn
351	2.41	0.70	0.02	1.11	0.08	1.68	50.96	<0.01	<0.01	<0.01	0.01	0.15	0.20	42.43	0.05	0.06	0.06	0.08	0.02	......	100.02	Downs Schaaf
414	34.58	0.47	0.04	0.70	0.41	0.51	34.49	......	.....	0.11	0.09	0.09	0.40	27.40	0.02	0.16	0.14	0.08	.....	......	99.69	E. Chadbourn
408	0.81	0.27	0.04	2.14	0.32	0.83	51.73	......	.....	0.05	0.04	0.08	0.46	42.29	0.02	0.33	0.19	0.13	......	......	99.73	E. Chadbourn
401	1.63	0.62	0.15	1.18	0.51	0.72	51.81	......	......	0.08	0.12	0.08	0.68	41.91	0.02	0.16	0.14	0.12	......	......	99.93	E. Chadbourn
410	2.53	0.79	0.33	1.17	0.07	0.77	51.70	......	......	0.05	0.16	0.10	0.62	41.43	0.04	0.19	0.09	0.07	......	......	100.11	E. Chadbourn
323	3.35	1.40	0.02	0.86	0.74	1.08	50.28	<0.01	<0.01	0.02	0.04	0.14	0.41	41.10	0.03	0.12	0.04	0.15	0.22	0.02	100.02	Downs Schaaf
329	1.29	0.49	0.02	0.71	0.08	0.70	53.27	<0.01	<0.01	<0.01	0.02	0.08	0.12	42.88	0.02	0.15	0.02	0.10	0.09	.....	100.04	Downs Schaaf
334	3.97	1.55	0.02	0.90	0.11	1.19	49.97	<0.01	<0.01	0.01	0.03	0.18	0.45	40.96	0.06	0.15	0.05	0.14	0.25	0.02	100.01	Downs Schaaf
331	2.07	0.96	0.02	0.83	0.65	1.16	51.51	<0.01	<0.01	<0.01	0.02	0.16	0.27	42.10	0.04	0.16	0.04	0.18	0.02	.....	100.19	Downs Schaaf
333	3.68	1.47	0.03	0.95	0.49	1.04	50.14	<0.01	<0.01	0.03	0.10	0.19	0.41	40.91	0.06	0.17	0.07	0.12	0.22	0.02	100.10	Downs Schaaf
319	4.86	2.12	0.07	0.86	0.75	1.10	48.50	<0.01	<0.01	0.03	0.07	0.14	0.62	39.70	0.09	0.16	0.08	0.20	0.50	0.04	99.89	Downs Schaaf
1010	1.70	0.36	1.74	.....	.....	1.51*	92.75**	.....	.....	.....	.....	0.12	.....	.....	0.03	0.25	S 0.18	.....	.....	.....	99.64	D. J. Demorest
1011	9.71	0.68	2.09	.....	.....	1.19*	84.41**	.....	.....	.....	.....	0.32	.....	.....	0.09	0.14	S 0.9	.....	.....	.....	98.72	D. J. Demorest
318	3.62	1.25	0.03	0.98	0.04	0.63	51.12	<0.01	<0.01	0.02	0.05	0.11	0.38	41.30	0.09	0.18	0.08	0.20	0.06	.....	100.14	Downs Schaaf
320	6.77	1.28	0.02	0.74	0.05	0.60	49.63	<0.01	<0.01	0.02	0.05	0.12	0.40	39.95	0.08	0.15	0.08	0.16	0.02	.....	100.12	Downs Schaaf
317	2.41	0.74	0.03	0.70	0.02	0.55	52.50	<0.01	<0.01	0.02	0.04	0.06	0.21	42.12	0.08	0.21	0.18	0.25	0.01	.....	100.13	Downs Schaaf
81	94.72	0.59	0.10	0.55	0.14	0.02	1.29	.....	.....	0.06	0.09	0.50	0.65	1.07	0.09	0.14	0.01	<0.01	0.24	0.03	100.28	Downs Schaaf
1012	1.80	1.80	1.63	.....	.....	0.64	51.23	.....	.....	.....	.....	1.50	.....	.....	0.02	0.15	0.79	.....	.....	.....	....	D. J. Demorest
1013	0.69	0.78	1.01	.....	.....	0.12	53.92	.....	.....	.....	.....	0.81	.....	.....	Trace	0.12	0.26	.....	.....	.....	....	D. J. Demorest
80	1.90	1.06	1.10	2.01	0.06	0.44	51.05	.....	.....	0.02	0.04	0.14	0.35	41.62	0.04	0.16	0.02	0.21	0.06	.....	100.28	Downs Schaaf
390	0.41	0.35	0.39	1.14	<0.01	0.66	53.52	<0.01	<0.01	0.08	0.14	0.08	0.05	42.24	0.01	0.09	0.83	0.01	0.15	0.02	100.17	Nalin Labs.
385	9.10	2.98	1.53	1.07	<0.01	3.08	43.28	<0.01	0.098	0.17	0.38	0.15	0.28	37.46	0.15	0.05	0.15	0.02	0.21	0.03	100.188	Nalin Labs.
378	11.11	2.28	0.02	0.93	<0.01	7.14	37.03	<0.01	0.12	0.02	<0.01	0.16	3.25	37.34	0.01	0.03	0.06	0.09	0.39	0.05	100.03	Nalin Labs.
405	8.69	1.72	0.32	0.89	0.07	5.49	42.55	.....	.....	0.09	0.30	0.13	0.64	38.85	0.07	0.03	0.03	0.10	.....	.....	99.97	E. Chadbourn
335	3.53	1.70	0.03	1.12	0.05	1.02	50.16	<0.01	<0.01	0.03	0.10	0.25	0.49	41.00	0.08	0.18	0.09	0.11	0.14	0.01	100.09	Downs Schaaf
338	1.80	0.77	0.08	0.73	0.08	0.99	52.27	<0.01	<0.01	0.02	0.11	0.19	0.20	42.45	0.05	0.15	0.03	0.13	0.04	.....	100.09	Downs Schaaf

* $MgO.CO_2$

** $CaO.CO_2$

*** $Al_2O_3.3H_2O$

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